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UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Fisheries Science Center
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April 3, 1997

MEMORANDUM FOR: F/NW - William Stelle
F/SW - William Hogarth

THRU: F/NWC - Usha Varanasi

FROM: F/NWC1 - Michael H. Schiewe

SUBJECT: Conclusions regarding the Updated Status of Coho Salmon from Northern California and Oregon Coasts

The West Coast Salmon Biological Review Team (BRT) has updated its assessment of the status of coho salmon from Northern California and Oregon coasts, originally completed in 1994 as part of the coast-wide coho salmon status review. In July 1995, NMFS proposed that coho salmon from this area belonged to two Evolutionarily Significant Units (ESUs), or "species," and proposed that both were "threatened" under the ESA. The first attached report summarizes the conclusion from this updated review. The BRT has not completed its updated review of the status of coho salmon from the Columbia River, Washington, and southern British Columbia, which will form the basis of a future report.

Two additional documents are attached. The first is a memorandum from T. Wainwright to M. Schiewe that describes and critiques ODFW's habitat-based coastal coho salmon sustainability model. This model was considered by the BRT as part of its risk evaluation for Oregon coast coho salmon. Dr. Wainwright's memo provides considerably greater detail about the model than the summary provided in the BRT conclusions memo described above.

The second document is a memorandum from S. Jacobs (Oregon Department of Fish and Wildlife--Corvallis) to R. Waples and others at NMFS regarding the occurrence of hatchery fish in ODFW spawner escapement estimates. This memo is included because of the considerable uncertainty about the number of natural spawners that are of natural and hatchery origin on the Oregon coast. Naturally spawning hatchery fish are one of several risk factors considered in this status review update. It reports estimates not available to the BRT at the time of the last meeting. The BRT review used natural spawner abundance estimates from ODFW based on their stratified-random survey (SRS) method. In that method, a total spawner estimate is generated for each stratum (geographic area) and then adjusted to remove an estimate of naturally-spawning hatchery fish. We had noticed that the adjustments used by ODFW seemed low in comparison with the percentage of naturally spawning hatchery fish reflected in the ODFW scale analysis dataset, which Laurie Weitkamp, from our status review team, collated and summarized. Some time ago we asked ODFW for clarification of their methods for adjusting the spawner estimates for hatchery fish, but we did not receive a detailed answer until a week after the BRT meeting, when Tom Wainwright, Robin Waples, and Steve Stone participated in a conference call with Steve Jacobs.

Based on that call, it appears that the methods ODFW has used to "subtract out" naturally spawning hatchery fish from estimates of spawning escapement is subjective and relies heavily on professional judgement. In addition, it seems clear that the method has some built-in biases. For example, Jacobs said that he does not use scale or tag data to estimate the proportion of natural spawners if the sample size is low (less than 20 fish). However, the result is that no adjustment is made in these cases, which is equivalent to assuming that 100% of the spawners in these areas were naturally produced. At our suggestion, Jacobs redid the calculations using what should be a largely unbiased method--expanding hatchery/wild ratios based on scale pattern analysis in a random sample of the SRS surveys. The new spawner abundance estimates (based on averages for years 1990-1996) are approximately 15% below those from the old method on an ESU-wide average (see attached document, Table 2). Because hatchery strays are more of a problem on the northern part of the coast, changes from the previous estimates are much higher in some basins than this average (e.g. Salmon River--69% below original estimate, Necanicum River and Elk Creek--43%, Tillamook Bay--33%, Siuslaw River--24%).

These new estimates, however, must also be considered with caution. Jacobs feels that in some basins the scale pattern analyses may not be a reliable indicator of hatchery/wild origin, and he provided data for 1996 that showed large differences between estimates based on coded-wire-tags and scale pattern analyses in some basins. In our judgement, the original estimates provided by ODFW (and which the BRT used in its evaluations) are biased upwards, but it is difficult to determine the magnitude of the bias. Overall abundance for the ESU is likely to be lower than the estimates available to the BRT, and if so the biases are likely to be worst in the northern coastal area that is most at risk. ODFW has not provided adjusted estimates on an annual basis, so we cannot determine whether revising the spawner estimates would affect population trend estimates.

Please contact Robin Waples (206 860-3254), Tom Wainwright (206 860-3266), or myself if you need clarification of any of this material.

Attachments

cc: F/NWO - Freeman
F/NWO1 - Robinson
F/NWO3 - Wyland
GCNW - Bancroft
GCNW - Rowland
F/PR - Diaz-Soltero

Status Review Update for Coho Salmon from the Oregon and Northern California Coasts

Prepared by the
West Coast Coho Salmon Biological Review Team[1]

28 March 1997

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[1]The Biological Review Team (BRT) for West Coast coho salmon included Peggy Busby, Robert Emmett, Dr. Jeffrey Hard, Dr. Robert Iwamoto, Dr. Orlay Johnson, Dr. Robert Kope, Dr. Conrad Mahnken, Gene Matthews, Dr. Michael Schiewe, David Teel, Dr. Thomas Wainwright, William Waknitz, Dr. Robin Waples, Laurie Weitkamp, Dr. John Williams, and Dr. Gary Winans, all from the Northwest Fisheries Science Center (NWFSC), Dr. Peter Adams from the Southwest Fisheries Science Center (SWFSC), and Gregory Bryant from the NMFS Southwest Region.

TABLE OF CONTENTS

SUMMARY

This document reports conclusions of the Biological Review Team (BRT) regarding two ESUs of coho salmon that were proposed for listing in 1995. Based on new and updated information, in addition to information considered in the original status review, the BRT concluded that both the Southern Oregon/Northern California Coasts ESU and the Oregon Coast ESU were likely to become endangered, assuming present conditions and management policies continue into the future. The BRT also evaluated the risks faced by these ESUs under the assumption that harvest and hatchery reforms proposed by the Oregon Coastal Salmon Restoration Initiative draft Conservation Plan would be implemented. The BRT did not evaluate habitat related elements of the plan. The BRT concluded that although the harvest and hatchery elements of the Plan could be expected to provide some benefits to the Southern Oregon /Northern California Coasts ESU, they would not substantially affect extinction risk. Likely benefits of the proposed measures are more predictable and more substantial for the Oregon Coast ESU, and about half of the BRT members felt that implementation of the measures would reduce risk enough to move the ESU out of the "likely to become endangered" category. The remaining BRT members were concerned that the proposed measures would not be sufficient to alleviate risks due to declining productivity and habitat degradation.

BACKGROUND

In 1993 the National Marine Fisheries Service (NMFS) received several petitions to list coho salmon under the U.S. Endangered Species Act (ESA), and shortly thereafter NMFS formed a Biological Review Team (BRT) to initiate a coast-wide status review of coho salmon from southern British Columbia, Washington, Oregon, and California. Based on the results of this review (Weitkamp et al. 1995) and other information regarding conservation measures and factors for decline, in 1995 NMFS identified six evolutionarily significant units (ESUs) for West Coast coho salmon and proposed that the three southern-most ESUs be listed as threatened species under the ESA. At that time, NMFS also identified two other ESUs as candidates for possible future listing and determined that listing was not warranted for one ESU (60 FR 38011, July 25, 1995). In October 1996, NMFS announced a final listing of the southern-most ESU (Central California coast) as a threatened species, and postponed for 6 months a decision on the status of the two other ESUs that had been proposed for listing in 1995 (61 FR 56138, October 31, 1996).

This document provides the final BRT conclusions for these two ESUs--the Southern Oregon/Northern California Coasts ESU and the Oregon Coast ESU. It supplements the original status review report (Weitkamp et al. 1995), providing updated information and analysis received for northern California and Oregon Coast coho salmon since the time that review was conducted. In the first section of this document, we review previous conclusions, comanager and peer-review comments and other information received. In the second section, new information relating to extinction risk is discussed. The final section summarizes the BRT conclusions regarding these issues for northern California and Oregon coast coho salmon.

Key Questions in ESA Evaluations

In determining whether a listing under the ESA is warranted, two key questions must be addressed :

1) Is the entity in question a "species" as defined by the ESA?
2) If so, is the "species" threatened or endangered?

These two questions are addressed separately in this report.

Secondly, if any natural populations are listed under the ESA, then it will be necessary to determine the ESA status of all associated hatchery populations. Evaluations of the ESA status of hatchery populations in ESUs that were proposed for listing are included in this document.

SUMMARY OF PREVIOUS CONCLUSIONS

ESU Determinations

As described in the status review (Weitkamp et al. 1995), the BRT considered evidence from numerous sources to identify ESU boundaries. In general, evidence from physical environment and ocean conditions/upwelling patterns, estuarine and freshwater fish and terrestrial vegetation distributions, and coho salmon river entry and spawn timing and marine coded-wire-tag recovery patterns proved to be most informative. Genetic data were used to indicate relative levels of reproductive isolation between populations and groups of populations. Based on this information, the BRT identified six ESUs for west coast coho salmon: 1) Central California coast, 2) Southern Oregon/Northern California Coasts, 3) Oregon Coast, 4) Lower Columbia River/Southwest Washington Coast, 5) Olympic Peninsula, and 6) Puget Sound/Strait of Georgia.

Assessment of Extinction Risk

Based on the best information available at the time of the original status review, which often consisted of data only through 1993, the BRT identified a geographic trend in the status of coho salmon stocks south of the Canadian border, with the southernmost and eastern-most stocks in the worst condition. Throughout the regions reviewed, there had been recent declines in coho salmon abundance, and 1994 runs were predicted to be the worst on record in many river basins. The following conclusions were reached for the two proposed ESUs.

Southern Oregon/Northern California Coasts

All coho salmon stocks between Punta Gorda and Cape Blanco were depressed relative to past abundance, but there were limited data to assess population numbers or trends. The main stocks in this region (Rogue River, Klamath River, and Trinity River) were heavily influenced by hatcheries, apparently with little natural production in mainstem rivers. The apparent declines in production in these rivers, in conjunction with heavy hatchery production, suggested that the natural populations were not self-sustaining. The status of coho salmon stocks in most small coastal tributaries was not well known, but these populations were small. There was unanimous agreement among the BRT that coho salmon in this ESU were not in danger of extinction, but were likely to become endangered in the foreseeable future if present trends continued.

There was substantial uncertainty regarding abundance of coho salmon and the influence of hatchery production on natural populations.

Oregon Coast

There were extensive survey data available for coho salmon in this region. Overall, spawning escapements had declined substantially during this century, and may have been at less than 5% of their abundance in the early 1900s. Average spawner abundance had been relatively constant since the late 1970s, but pre-harvest abundance had declined. Average recruits-per-spawner may also have declined. Coho salmon populations in most major rivers appeared to have had heavy hatchery influence, but some tributaries may have been sustaining native stocks. The BRT concluded that coho salmon in this ESU were not at immediate risk of extinction but were likely to become endangered in the future if present trends continued.

For this ESU, information on trends and abundance were better than for the more southerly ESUs. Main uncertainties in the assessment included the extent of straying of hatchery fish, the influence of such straying on natural population trends and sustainability, the condition of freshwater habitat, and the influence of ocean conditions on population sustainability.

COMANAGER AND PEER REVIEW COMMENTS

Comments on the status review were received from California Department of Fish and Game (CDFG) (1995), Oregon Department of Fish and Wildlife (ODFW) (1994, 1995b), and Washington Department of Fish and Wildlife (WDFW) (1995), as well as peer review comments by two anonymous reviewers (Anonymous 1995a, 1995b). Because this document is limited to discussion of the Southern Oregon/Northern California Coasts and Oregon Coast ESUs, comments pertaining to the other ESUs are not discussed here.

One peer reviewer's comments related primarily to interpretation of genetic data in California (Anonymous 1995a). CDFG (1995) concurred with NMFS' designation of ESU boundaries in California and with the proposed listing of the Central California Coast and the Southern Oregon/Northern California Coasts ESUs as threatened.

The other peer reviewer's most substantive comments pertained to the analysis of abundance data for the Oregon coast and the Olympic Peninsula. These comments were also voiced by ODFW (1994). The thrust of their argument was that the decline on the Oregon coast was overstated in the status review because terminal runs were expanded using Oregon Production Index (OPI) harvest rates, while more precise and representative harvest rates can be calculated from coded-wire-tag (CWT) data. If these rates are used, the decline in Oregon coast natural (OCN) coho salmon does not appear to be as sharp. Secondly, they noted that the BRT used primarily escapement data on the Oregon coast whereas terminal run size was used for the Olympic Peninsula ESU, and they argued that this was an unfair comparison. If the BRT examined similar data, they asserted, similar trends for the Oregon coast and the Olympic Peninsula would be seen. Both (Anonymous 1995b, ODFW 1994, 1995b) also contended that the BRT had overstated the impact of hatchery fish on natural spawning population on the Oregon coast. ODFW (1994) further maintained that population levels at <5% of historic levels should not be a concern because the habitat is only capable of supporting 10% of historic abundance, so recent spawning escapements are at, or near, maximum sustainable yield levels.

OTHER INFORMATION RECEIVED

Since completing the status review for coastwide coho salmon (Weitkamp et al. 1995), the NMFS has received new and updated information on coho salmon in British Columbia, Washington, Oregon, and California that is critical to assessing the current status of coho salmon ESUs. This new information generally consists of updates of existing data series, new data series, new analyses of various factors, and new information about management practices. As part of this new information, NMFS received several reports in fall 1996 that provided substantial new information about risks faced by many coho salmon ESUs.

NMFS also received numerous draft Oregon Coastal Salmon Restoration Initiative (OCSRI) Science Team products (State of Oregon 1996), including the results of three approaches to population viability analysis (Chilcote 1996; Nickelson and Lawson 1996, 1997; Schreck et al. 1996). In February 1997 we also received a revised draft OCSRI plan (State of Oregon, 1997). Specific consideration was given to:

1) 1996 adult returns
2) updated information on naturally-spawning hatchery fish
3) effects of the 1995/1996 floods
4) results of population modeling work
5) proposed harvest and hatchery reforms

These are discussed in more detail later.

In November 1996, NMFS Northwest and Southwest Fisheries Science Centers sponsored a symposium/workshop on "Assessing Extinction Risk for West Coast Salmon" (Seattle, 13-15 November 1996). The objective of the workshop was to evaluate scientific methods for assessing various factors contributing to extinction risk of Pacific salmon populations. The final report on panel recommendations is not yet available, but a preliminary summary of key recommendations was considered by the BRT in this review. Most of these recommendations require long-term development of improved methods, and thus could not be applied in this review.

ESU DEFINITIONS

As no substantive comments or new information were received on the proposed ESU definitions, these remain unchanged. The Southern Oregon/Northern California Coasts ESU includes naturally-spawning coho salmon populations from Punta Gorda to Cape Blanco, and the Oregon Coast ESU includes populations from Cape Blanco to the mouth of the Columbia River.

DISCUSSION OF EXTINCTION RISK FACTORS

In this section, we discuss important new information and analyses for several risk factors (population abundance, population trends and production, habitat conditions, and hatchery production and genetic risks) for the two ESUs under consideration. The following section summarizes these factors and draws conclusions regarding the degree of extinction risk facing each ESU based on this new information as well as that in Weitkamp et al. (1995).

Hatchery Production and Genetic Risks

The following discussion is based on the summary table of artificial propagation factors by basin (Appendix Table 1).

Number of hatcheries in each ESU

In general, there is a latitudinal trend in the number of coho salmon hatcheries along the west coast, with more hatcheries in the northern than in the southern ESUs. Because the majority of hatchery releases occur in-basin, the naturally spawning populations in basins that contain hatcheries are the most likely to have hatchery influence. Similarly, because most out-of-basin releases occur in adjacent basins, naturally spawning populations in basins that don't themselves contain hatcheries but are near basins that do are more likely to have hatchery impacts than populations that are farther away from hatcheries. The production capacity of hatcheries also follows a latitudinal trend, with many northern hatcheries capable of producing several millions smolts each year, while more southern hatcheries produce tens or hundreds of thousands of fish annually.

Number of fish released and stocks used

We have summarized various statistics about the number and types of fish released into each basin (Appendix Table 1). This information consists of the number of stocks released, the total number of fish released, the percentage of releases that consisted of "native" fish (stocks whose name is either the basin or subbasin name), and the percentage of releases that consisted of smolts (as opposed to fry). Other things being equal, the more fish that are released, the more likely natural populations are to be impacted by hatchery fish. Similarly, the more genetically similar hatchery fish are to natural populations they spawn with, the less change there will be in the genetic makeup of future generations. We included the percentage of smolts released because 1) smolts generally spend less time in freshwater before migrating to sea, reducing the opportunity for interactions with naturally produced fish, and 2) hatchery fish released as smolts typically survive at a rate much higher than hatchery fish released as fry.

Hatchery releases listed in Appendix Table 1 are separated into two time periods, 1950-85 and 1986-present, to emphasize changes in release practices that occurred in the 1980s. For many basins, the number of stocks released, the size and frequency of annual releases, and the percentage of smolts releases is quite different between the two periods (fewer stocks, fewer fish planted, higher percentage smolts in later years), in response to wild fish policies in Oregon and Washington. Other basins, however, have seen dramatic increases in the number of fish released.

Natural production

Although the absolute number of fish released in a basin is related to the potential impact those fish will have on natural populations, the number of fish released relative to the size of the natural population is, in some ways, a more important predictor of hatchery impacts. For example, a release of 10,000 fish in a natural population of 1,000 fish obviously has a much greater potential impact than the same release on a population of 100,000 fish. We have provided two measures of natural abundance--recent natural spawner abundance and miles of habitat--for each basin. These measures are provided to help evaluate the relative number of released fish, and the relative "health" of current populations. For example, a key question is, based on the number of fish and the miles of habitat, does there appear to be sufficient vacant habitat in which hatchery fish could survive, or are large numbers of natural fish already occupying that habitat? Miles of habitat are used as a gross substitute for data on carrying capacity of habitats, which are not available coastwide.

One complicating factor in estimating relative size of hatchery releases, particularly those that occurred several decades ago, is that the size of many natural populations have undergone dramatic declines. Consequently, although the frequency and number of fish released in many basins has been declining, so has the natural population that would be impacted. Whether declines in the number of fish released and the size of natural populations have kept pace with each other remains to be determined.

Hatchery fish spawning naturally

ODFW and an anonymous reviewer argued that, in the status review, the BRT overestimated the risks to Oregon coast populations because straying of hatchery fish to natural spawning areas was only a significant factor in a few, isolated areas (Anonymous 1995b, ODFW 1995b). In order to address this comment, we assembled data on the proportion of hatchery fish that spawn naturally in each ESU, based on scale analysis, CWT recoveries, or other marks (fin clips) (summarized in Appendix Table 1). Data provided by ODFW (Borgerson 1991, 1992, 1997; Nickelson and Jacobs 1996) indicated that the proportion of hatchery fish that spawned naturally was high in many basins along the Oregon coast (Table 1, Appendix Table 1).

After reviewing NMFS' compilation of their data on Oregon coast hatchery fish identified in natural spawning areas by scale analysis, ODFW staff argued that it failed to represent actual trends in straying within basins (T. Nickelson, S. Jacobs, J. Nicholas, Pers. comm., Aug. 1996). They felt that estimated percentages of naturally spawning hatchery fish shown in Table 1 were upwardly biased because 1) locations where scales were collected did not represent conditions in the entire basin, and 2) some fish may have been mistakenly identified as hatchery fish. ODFW also provided a new dataset that they felt better represented actual conditions (Nickelson and Jacobs 1996). In many cases, the percentage of hatchery fish identified in natural spawning areas is lower is the new dataset, and sites with particularly high percentages are identified as hatchery sites (Table 1)..

The BRT also received scale data for natural spawning fish returning in 1996/7 (Borgerson 1997). The 1996/7 adult returns reflect the first year (1995) of substantially decreased hatchery smolt releases from the northern Oregon hatcheries and increased releases in the Yaquina Basin (Table 2).. The 1996/7 scale analysis data are provided in Table 1 for comparison to previous years' estimates. The scale data suggest that in the Trask and other Tillamook Bay Rivers, the proportion of hatchery fish spawning naturally has decreased, while in the Siletz, Salmon and Yaquina it has remained relatively constant or increased. These conclusions should be regarded as tentative, given the small sample sizes in 1996 and the potentially non-random method of sample collection.

Spawn timing

An additional comment from ODFW concerning the assessment of risks from artificial propagation was that there is substantial and deliberate separation of spawn timing of natural and hatchery populations of coho salmon along the Oregon coast, and that earlier-spawning hatchery fish have little reproductive success because the earlier timing makes their redds prone to destruction by early fall storms. ODFW argued that this difference in timing was large enough that even if hatchery fish strayed to spawning grounds, they would not be spawning with natural fish and therefore would not have permanent genetic impacts.

To evaluate this claim, the BRT examined information on spawn timing for hatchery and natural populations in the ESUs (summarized in Appendix Table 1). Advancement of spawn timing is a common practice in coho salmon to allow extended fishing opportunity and separation of hatchery and wild populations. However, one of the requirements of advancing spawn timing is that a hatchery has more fish than it needs and therefore may select spawners from the earlier portion of the run. At most California hatcheries, returns to the facility are generally small enough that most or all fish have to be spawned to meet eggtake, and therefore fish from throughout the run contribute to the next generation. Consequently, although the BRT has no timing information for both hatchery and natural populations from the same California basins, it is expected that hatchery spawn timing has not changed dramatically at California hatcheries, and still greatly overlaps natural spawn timing.

The BRT generally did not find large timing differences for Oregon basins with both hatchery and natural spawn timing data. Although spawn timing of hatchery and naturally spawning fish was clearly different in some basins, there was considerable overlap in recorded spawn timing in others. Furthermore, for those Oregon basins in which there were apparent differences, fish continued to return to the hatchery after spawning was completed, suggesting that the hatchery populations were capable of spawning (and presumably did spawn naturally) later than the times reported by the hatchery.

In October 1996, ODFW provided new information on timing of naturally spawning fish identified as of hatchery or natural origin based on scale analysis, from selected areas known to high percentages of hatchery fish (Nickelson and Jacobs 1996). This timing data, most of which came from the Nehalem River, indicated some separation of hatchery and wild spawn timing. This difference in Nehalem hatchery and wild spawn timing is consistent with the BRT's analysis, which indicated clear differences between the two in this basin. However, it is unclear whether such separation occurs in other basins, particularly those identified as having less separation in hatchery and wild spawn timing.

Habitat Conditions

Habitat Requirements of Coho Salmon

Coho salmon spend their first 15-20 months in streams and rivers and are therefore particularly vulnerable to adverse impacts of past and current land use practices. Reeves et al. (1989) defined physical habitat requirements for coho salmon at each freshwater life history stage. With the exception of spawning habitat, which consists of small streams with stable gravels, summer and winter freshwater habitats most preferred by coho salmon consist of quiet areas with low flow, such as backwater pools, beaver ponds, dam pools, and side channels. Habitats used during winter generally have greater water depth than those used in summer, and also have greater amounts of large woody debris (LWD). Production of wild coho salmon smolts in streams on the Oregon coast is probably limited by the availability of adequate winter habitat (Nickelson et al. 1992).

Habitat factors other than physical features, such as nutrient and food availability, limit production of juvenile coho salmon but the procedures for identifying these biological factors are not well developed, and biological habitat factors are not commonly evaluated by fishery managers.

Historical Conditions

The role that large woody debris plays in creating and maintaining coho salmon spawning and rearing habitat in all sizes of streams has been recognized for only the past 25 years. Before this time, up to 90% of the funds for fish-habitat enhancement went for removal of wood debris in streams (Sedell and Luchessa 1982).

Descriptions of pre-development conditions of rivers in Washington and Oregon that had abundant salmonid populations suggest that even big rivers had large amounts of instream LWD. which not only completely blocked most rivers to navigation but also contributed significantly to trapping sediments and nutrients, impounding water, and creating many side channels and sloughs (Sedell and Froggatt 1984, Sedell and Luchessa 1982). Many streams consisted of a network of sloughs, islands, and beaver ponds with no main channel. For example, portions of the Willamette River reportedly flowed in five separate channels, and many coastal Oregon rivers were so filled with log jams and snags they could not be ascended by early explorers. Most rivers in coastal Washington and Puget Sound were similarly blocked by large woody debris, snags, and instream vegetation. Sedell and Luchessa (1982) compiled a partial list of major rivers that were impassable for navigation in the mid-1800s because of large (100-1500 m-long) log jams; this list included 11 rivers in Oregon and 16 in Washington.

Besides clearing rivers for navigation, extensive "stream improvements" were accomplished to facilitate log drives. These activities included blocking off sloughs and swamps to keep logs in the mainstream and clearing boulders, trees, logs, and snags from the main channel. Smaller streams required the building of splash dams to provide sufficient water to carry logs. Scouring, widening, and unloading of main-channel gravels during the log drive may have caused as much damage as the initial stream cleaning. Stream cleaning continued through the mid-1970's in many areas, not only for flood control and navigation but as a fisheries enhancement tool as well. Debris in streams was viewed as something that would either impede or block fish passage and as a source of channel destruction by scour during storm-induced log jam failures.

Habitat Modification

The past destruction, modification, and curtailment of freshwater habitat for steelhead was reviewed in the "Factors for Decline" document published as a supplement to the notice of determination for West Coast Steelhead under the ESA (NMFS 1996a). Since the range of coho salmon and steelhead overlap extensively, this document serves as a catalog of past habitat modification for coho salmon as well as steelhead. NMFS (1996a) documented habitat losses within the range of west coast coho salmon due to: (1) hydropower development (juvenile and adult passage problems); (2) water withdrawal, conveyance, storage, and flood control (resulting in insufficient flows, stranding, juvenile entrainment, instream temperature increases); (3) logging and agriculture (loss of LWD, sedimentation, loss of riparian vegetation, habitat simplification); (4) mining (gravel removal, dredging, pollution); and (5) urbanization (stream channelization, increased runoff, pollution, habitat simplification). Lichatowich (1989) also identified habitat loss as a significant contributor to stock declines of coho salmon in Oregon's coastal streams.

A number of authors have attempted to quantify overall anadromous fish habitat losses in areas within the range of west coast coho salmon. Gregory and Bisson (1997) stated that habitat degradation has been associated with greater than 90% of documented extinctions or declines of Pacific salmon stocks. It has been reported that up to 75% and 96% of the original coastal temperate rainforest in Washington and Oregon, respectively, has been logged (Kellogg 1992), and that only 10-17% of old-growth forests in Douglas-fir regions of Washington and Oregon remain (Norse 1990, Speis and Franklin 1988). California has reportedly lost 89% of the state's riparian woodland to various land use practices (Kreissman 1991). Within California, Fisk et al. (1966) stated that over 1,600 km of streams had been damaged or destroyed as fish habitat by 1966. Approximately 80-90% of the original riparian habitat in most western states has been eliminated (NMFS 1996a). For example, Edwards et al. (1992) reported that 55% of the 43,000 stream kilometers in Oregon were moderately or severely affected by non-point source pollution.

Large, deep-pool habitats are a particular requirement of high quality stream habitat for coho salmon. FEMAT (1993) reported that there has been a 58% reduction in the number of large, deep pools on national forest lands within the range of the northern spotted owl in western and eastern Washington. Similarly, there has been as much as an 80% reduction in the number of large, deep pools in streams on private lands in coastal Oregon (FEMAT 1993). Overall, the frequency of large pools has decreased by almost two-thirds between the 1930s and 1992 (FEMAT 1993, Murphy 1995).

Schmitt et al. (1994) pointed out that coho salmon make extensive use of estuarine habitat on migration to the sea and that overall losses since European settlement, by area, of intertidal habitat were 58% for Puget Sound in general and 18% for the Strait of Georgia. Four river deltas (the Duwamish, Lummi, Puyallup, and Samish) have lost greater than 92% of their intertidal marshes (Simenstad et al. 1982, Schmitt et al. 1994). Dahl (1990) reported that over 33% of wetlands in Washington and Oregon have been lost and that much of the remaining habitat is degraded.

The 1992 Washington State Salmon and Steelhead Stock Inventory identified numerous land use practices or habitat factors that have had a detrimental impact on coho salmon habitat for each of 90 recognized coho salmon stocks in Washington (WDF et al. 1993). Dominant land-use practices and habitat factors cited in this report differ to some extent between coho salmon ESUs, with the Puget Sound/Strait of Georgia ESU incurring greatest impact from urbanization and agricultural practices, the Olympic Peninsula ESU incurring greatest impact from forest practices, and the Lower Columbia River/Southwest Washington Coast ESU incurring greatest impact from forest and agricultural practices (WDF et al. 1993).

Weitkamp et al. (1995) pointed out the rarity of specific quantitative assessments of coho salmon habitat degradation and its causes. Two studies addressing this topic have subsequently appeared. Beechie et al. (1994) estimated a 24% and 34% loss of coho salmon smolt production capacity of summer and winter rearing habitats, respectively, in the Skagit River, Washington since European settlement. Beechie et al. (1994) identified the three major causes for these habitat losses, in order of importance, as hydromodification, blocking culverts, and forest practices. Similarly, McHenry (1996) estimated that since European settlement, Chimacum Creek, Washington (northwest Puget

Sound) had lost 12%, 94% and 97% of its spawning, summer rearing, and winter rearing habitats for coho salmon, respectively. McHenry (1996) stated that these habitat losses were due to logging, agricultural clearing, channelization, drainage ditching, groundwater withdrawal, and lack of woody debris.

Logging, agriculture, urbanization, grazing, and mining have led to large reductions in essential summer and winter rearing habitat for coho salmon (backwater pools, beaver ponds, side channels, off-channel areas, deep lateral scour pools, dam pools, and stream margins where LWD and boulders form deep pockets of water) in Washington, Oregon, and northern California. Loss of deep pool habitat make coho salmon vulnerable to high instream summer temperatures, winter flood events, lowered water quality, and predation by fish and birds due to lack of cover.

Effects of the February 1996 floods

Between November 1995 and April 1996, the Pacific Northwest experienced a rare series of storm and flood events. High winds, heavy rainfall, rapid snowmelt, numerous landslides and debris torrents, mobilization of large woody debris and high runoff occurred over portions of Oregon, Washington, Idaho, and Montana (USFS and USBLM 1996). These storms also had a potentially large effect on the survival Oregon coast coho salmon and the freshwater habitats upon which they depend. The following material summarizes the reported effects of the 1996 flood.

Making of the flood--The February flooding was the last major event of a winter with unusually severe weather. November 1995 was the third wettest on record in Portland (over twice the annual average) and also the warmest on record. Together, these events caused localized flooding and little snowpack accumulation in the Cascades. December brought a short, intense period of hurricane-strength winds to the Oregon coast, with gusts of 119 mph at Sea Lion Caves, followed by an extended dry period and continuing below-average snowpack. In January, snow pack in the Willamette Basin increased from 29% of average at the beginning of the month to 112% of average by month's end, due to precipitation and a short, extremely cold period.

Finally, February began with a wide-spread ice storm followed immediately by a surge of subtropical moisture stretching from the Umpqua Basin to Seattle, producing as much as 9 inches of precipitation in 24 hrs along the Oregon coast, and 12-25 inches of precipitation for the duration of the storm. The abnormally high rainfall and warm temperature, on top of already elevated streams levels and saturated soils, resulted in the floods of February 1996, considered to be 100-year floods in many Oregon coastal basins (Bush et al. 1997, USFS and USBLM 1996).

Landscape-scale habitat impacts--USFS and USBLM (1996) estimated landscape-scale habitat impacts from the February 1996 flood on federal lands in Washington and Oregon.

They identified the Wilson-Trask-Nestucca, Siuslaw, and Alsea Basins as experiencing landslides, gullies/surface erosion, bedload deposition, channel migration, and LWD deposition, and considered the Wilson-Trask-Nestucca area as one of four areas with the highest rates of disturbance from the flood, and Siuslaw as one of four areas with the second highest rates of disturbance from the flood.

Pacific Watershed Associates (PWA undated) conducted aerial surveys to provide an assessment of the nature, magnitude and spatial distribution of watershed erosion and impacts to streams channels in the middle Coast Range, including the Smith (Umpqua), Siuslaw, Alsea, and Yaquina Basins. They reported that areas with the greatest impact were typically watersheds with a combination of steep slopes, unstable bedrock geology, recent timber harvesting, high road densities and within the altitude range where precipitation intensities were probably the greatest, and included Hadsall and Knowles Creeks (Siuslaw) and Lobster Creek (Alsea). They also stressed that landslides were highly correlated with management activities, and originated from recent clear-cuts and forest roads at much higher frequencies than from wilderness or unmanaged areas. In addition to these observations, PWA concluded that the floods may have had long-term effects on watershed habitats. For example, they suggested that materials destabilized but not mobilized by the flood may remain unstable and therefore be susceptible to future flood events for some time, materials deposited in streams and rivers may persist for decades, and the impact to larger streams and rivers may actually increase over a period of several years as sediment is moved downstream. They also pointed to cost-effective restoration and management measures that may prevent or minimize future landslides.

Siuslaw National Forest (SNF 1996) staff surveyed 1.3 million acres of central Oregon coast forests using aerial photographs to assess the frequency and character of landslides. They detected 1686 slides, 41% of which were associated with roads, 36% with recent (<20 year old) clear cuts, and 23% with forested areas. They also found that subbasins in the southern portion of the area assessed (Coos, Umpqua, Siltcoos and Siuslaw) experienced 1½-2½ times more landslides by area than more northern areas. They attribute this difference to both landtype associations of the basins and the differential intensity of the storm as it moved onshore. They also determined that "stabilized" roads (those treated to reduce failure) were less likely to be the source of large (>2,000 cu. yds.) landslides than untreated roads.

Small-scale habitat impacts--With regard to impacts to in-stream coho salmon habitat, ODFW conducted random resurveys of habitat for 105 reaches since the floods (Moore and Jones 1997). This survey effort indicated that along the North Oregon Coast (Salmon River to Columbia River), 7.5% of habitats received "no impact" (no perceivable impact), 60% of habitats received "low impact" (high water and scour and deposition impacts), 28% received "moderate impact" (channel modified impact), and 3.4% received "torrents" (and of these levels associated with debris torrents or dam break floods) Along the Mid Coast (Siuslaw River to Devils Lake tributaries), 2% of habitats received "no impact." 91% received "low impact," 7% "moderate impact," 0.1% "torrents." Habitat changes were both positive and negative, depending on the area. For example, some areas had many new channels cut, which could provide off-channel habitat. In the Tillamook Bay Basin, the Wilson River received major negative impacts, while the Tillamook and Trask River Basins received little impact.

Bush et al. (1997) note that there were substantial changes in pool and riffle areas, large woody debris, and streambed substrates in stream following the floods, based on differences in stream reached initially surveyed in 1992-95 and resurveyed in 1996. Decreases in pool area ranged from 10-50%, and largely resulted from a 60% loss of beaver pond habitat. Bush et al. (1997) note that whether and when the beaver dams will be rebuilt remains uncertain, but beaver ponds provide critical overwinter coho salmon habitat. Large woody debris decrease by approximately 25% from the initial surveys, although much of the lost wood had been pushed up onto the floodplain or out of the active channel. Overall, large amounts of gravel were added to most streams, and new gravel bars were common.

Dewberry et al. (undated) documented changes in salmon habitats in Knowles Cr. (Siuslaw Basin). Twenty four debris torrents occurred in anadromous fish-bearing reaches of the basin, four of which exceeded 3,000 m^2. Although the floods had little impact on parts of the basin, including an old-growth section, other areas were highly affected.

There have also been several studies looking at flood effects on various restoration projects. For example, Bush et al. (1997) found that most instream structures in small streams survived the floods and created positive changes in stream habitat conditions, while structure in larger streams were less likely to still be functional following the floods.

Solazzi and Johnson (1996) also report on the effects of 1996 floods on restoration projects in the Alsea Basin. They report that overall, surface area of pools increased (37%) and surface area of riffles decreases (13%) due to the February flood. However, the resiliency of individual structures varied by location and type. In E.F. Lobster Cr., 18 of 27 (67%) of log sills still functioned as full spanning structures after the flood, while in Upper mainstem Lobster Cr., which experienced several large debris torrents, 9 of 24 full-spanning structure could not be found, and of the remaining 15, only 4 still created dammed pools--the rest are filled with sediment. Similar results were observed for other structures, such as alcoves and dam pools--most were still functional in E.F. Lobster Cr., but were not functioning in Upper mainstem Lobster Cr., due primarily to heavy sedimentation.

Siuslaw National Forest (SNF 1996) also evaluated 27 habitat improvements projects to determine whether they were still in place and functioning in the summer following the 1996 flood. More than 80% were still in place and providing at least partially improved habitat. They reported that the February flooding actually increased positive habitat changes (increased pool area and quality, increased cover complexity, and shift from bedrock. boulder and cobble substrates to gravel and sand) in project areas in many smaller streams, but not in adjacent, untreated reaches, nor in habitat improvement projects in large streams.

Effects on fish--Solazzi and Johnson (1996) reported that coho salmon in the Upper Mainstem Lobster Cr. had the lowest overwinter survival in 1995/96 (3%) observed since 1988, the first year it was estimated. East Fork Lobster had the second lowest overwinter survival rate (12%). They report that the largest decreases in population size were for age 0 fish, and that overwinter survival of older steelhead and cutthroat trout was similar to previous years, although it is not clear that the data support this second statement. The average fork length of coho smolts from Upper Mainstem Lobster Cr was 5 mm larger that previously observed. They concluded that the most significant impact of the flooding was on juveniles coho salmon eggs that were in the gravel at the time of the flood.

Solazzi and Johnson (1996) also provide estimates of coho survival for Tenmile and Cummins Creeks. Cummins Cr., which largely flows through a wilderness area, had low overwinter survival, with only about half the smolts of previous years. Tenmile had 50% survival (similar to previous years), but low smolt numbers were attributed to initial low population sizes.

In Knowles Cr., Dewberry et al. (undated) state that in the middle and lower Knowles, juvenile (brood year 1995) coho salmon were believed to be "largely wiped out" (p. 1), and juvenile chinook emigrating from the stream during spring 1996 were 20% as abundant as in previous years, despite the larger-than average number of adults entering the stream during fall 1995.

Population Abundance

Southern Oregon/Northern California Coasts ESU

For the Southern Oregon/Northern California Coasts ESU, the BRT has received revised estimates through 1995 of terminal run size at Huntley Park (lower Rogue River; T. Nickelson, ODFW, Pers. comm. 15 May 1996) and upstream passage at Gold Ray Dam (Anderson 1996) in the Rogue River Basin. The 1991-1995 geometric mean terminal run size estimated at Huntley Park is 1,420 natural coho salmon, with a corresponding ocean run size (based on harvest rate estimates for Cole Rivers Hatchery stock) of 1,642 (Appendix Table 2). In addition, there have been an average of 3,000 hatchery fish in the terminal run. For comparison, historical run size estimates for the late 1800s and early 1900s averaged above 50,000, but declined to less than 10,000 by the 1920s (ODFW 1995a). The 1995 run was the largest since 1988, but was estimated to be 70% hatchery production (10,047 hatchery and 4,221 natural fish estimated at Huntley Park). We have also received preliminary 1996 estimates of coho salmon run-size at Huntley Park on the lower Rogue River (S. Jacobs, pers. comm., 27 February 1997). Spawner abundance in

1996 is slightly above levels in 1994 and 1995 (Fig. 1). The most recent three years are all substantially higher than abundances in 1989-1993, and are comparable to counts at Gold Ray Dam (upper Rogue) in the 1940s.

The total run at Huntley Park included 60% hatchery fish in 1996, comparable to recent years. The vast majority of these hatchery fish return to Cole Rivers Hatchery, but we have no estimates of the number that stray into natural habitat. ODFW's estimates of returns at Huntley Park assume that almost all hatchery fish return to the hatchery, and total run size at Huntley Park is estimated from the ratio of the number of marked fish caught in Huntley Park seine surveys to an adjusted number of marked fish returning to the hatchery. In several recent years, counts at Gold Ray Dam have exceeded the run estimates at Huntley Park, which raises considerable doubt about the assumptions made.

Fish passage counts at Gold Ray Dam include fish returning to Cole Rivers Hatchery and to natural spawning areas in the upper Rogue River Basin. Counts of natural fish at the dam have fluctuated widely, ranging in the last 10 years from zero (1992) to above 3,000 (1988, 1994, 1995). Natural escapement to the upper basin was extremely low during the late 1960s and early 1970s, recovering only after production started at Cole Rivers Hatchery in the late 1970s. This fact, along with a strong correlation between natural and hatchery escapement (see discussion of trends below) suggests that natural coho salmon in the upper basin may largely be progeny of hatchery strays. Satterthwaite (1996, p. 1) concluded that recent increases in natural fish passing Gold Ray Dam are likely the result of increased spawning by stray hatchery fish, lower ocean harvest rates, and improved ocean survival.

The BRT has also received general comments by ODFW staff on distribution and abundance of coho salmon in the Oregon portion of this ESU (Confer 1996; Satterthwaite 1996; Vogt 1996). Data for assessing spawning activity in Rogue River tributaries and other streams in the ESU are quite limited, and mostly reflect sporadic adult and juvenile survey efforts by ODFW and USFS staff in the region. More surveys have been conducted in recent years, and the coastal SRS survey methodology will be expanded to areas south of Cape Blanco beginning this year. Within the Rogue River Basin, low to moderate numbers of adult and juvenile coho salmon have been found in numerous tributaries. Interpretation of some of the juvenile surveys has been confounded by prior fry releases or hatchbox programs that make it difficult to assess natural production, but there are several streams in the basin with regular observations of significant natural spawning. Outside the Rogue River Basin, the Oregon portion of this ESU has very limited coho salmon habitat, due to steep gradients with little overwintering habitat in lower streams. Of these streams, the Elk River has the best habitat, and is the only stream outside the Rogue where there have been consistent, recent observations of coho salmon, with escapement of about 100-200 fish. This is considerably below historical abundance estimates (1,500 fish in the 1927-28 season) (Confer 1996). Coho salmon are occasionally observed in other streams during spawner surveys or broodstock collection for chinook salmon. Over the past 10 years, a total of 5 coho salmon have been observed in Hunter Creek and the Pistol River. Higher numbers have been observed in the Chetco River (23 fish in 7 years) and Winchuck River (21 fish in 7 years). Because of very limited habitat, these streams probably never supported large populations. Confer (1996) suggests that the Chetco and Winchuck Rivers might be able to sustain populations of fewer than 200 coho salmon.

Information on presence/absence of coho salmon in northern California streams has been updated since the study by Brown et al. (1994) cited in the status review. More recent data (Table 3) indicates that the proportion of streams with coho salmon present is lower than in the earlier study (52% vs. 63%). In addition, the BRT received updated estimates of escapement at the Shasta and Willow Creek weirs in the Klamath River Basin, but these represent primarily hatchery production and are not useful in assessing the status of natural populations.

Oregon Coast ESU

For the Oregon Coast ESU, the BRT has received updated estimates of total natural spawner abundance based on stratified random survey (SRS) techniques, broken down by ODFW's Gene Conservation Groups (GCGs) and by smaller geographic areas (Nickelson 1996). These data are presented in Table 4. Total average (5-year geometric mean) spawner abundance for this ESU is estimated at about 45,000 (Appendix Table 2), slightly higher than the estimate at the time of the status review. Corresponding ocean run size is estimated to be about 72,000; this corresponds to less than one-tenth of ocean run sizes estimated in the late 1800s and early 1900s, and only about one-third of those in the 1950s (ODFW 1995a). Total freshwater habitat production capacity for this ESU is presently estimated to correspond to ocean run sizes between 141,000 under poor ocean conditions and 924,000 under good ocean conditions (OCSRI Science Team 1996b). Present abundance is unevenly distributed within the ESU, with the largest total escapement in the relatively small Mid/South Coast Gene Conservation Group (GCG), and lower numbers in the North/Mid Coast and Umpqua GCGs (Appendix Table 2).

For 1996 runs, we have received preliminary escapement estimates for major coastal river basins from SRS methods (State of Oregon 1997, Section 6), for the coastal lakes (S. Jacobs, pers. comm., 27 February 1997), and for the ESU as a whole from standard Peak Index and area under the curve (AUC) survey methods (S. Jacobs, op. cit.). We also have updated ocean exploitation estimates based on three methods: OPI estimated catch and escapement based on expansion of peak index surveys ("OPI-Index") for 1970-1996, OPI estimated catch and escapement based on SRS methods ("OPI-SRS") for 1990-1996, and results of the Fishery Regulation Assessment Model ("FRAM") for 1994-1996 (OPI-Index and FRAM from PFMC 1997a; OPI-SRS from Pete Lawson, Pers. comm., 25 February 1997). We have not received data to update our CWT-based index ("CWT") for 1996.

On the basis of these data, we have updated recent average escapement estimates (Table 4). We do not have sufficient 1996 data to update run-size estimates for individual basins or

GCGs, which remain current through 1995 (Appendix Table 2). The SRS escapement data indicate that on an ESU-wide basis, escapement has increased again in 1996, resulting in a four-fold increase since 1990 (Fig. 2). When looked at on a finer geographic scale, the far north coast still has very poor escapement, the north-central coast is mixed with strong increases in some streams but continued very poor escapement in others, and the south/central coast continues to have increasing escapement (Table 4).

Fishery recruitment forecasts for 1997 are slightly below the actual 1996 recruitment (PFMC 1997b). These forecasts are based only on ocean conditions with no inclusion of parental stock size or variation in freshwater production. 1997 runs will be produced from 1994 escapement, which was relatively low, and this brood was affected by the 1995-96 floods on the coast. Stream production studies conducted by ODFW (Solazzi and Johnson 1997) indicate that 1996 smolt production in four central coast study streams were lower than recent averages, with overwinter survival the lowest or second lowest on record for the two streams for which estimates were made, and that age 0 fish production was also low. They conclude that the "most significant impact was on juvenile coho salmon eggs that were in the gravel at the time of the flood." While this is a small sample size and may not reflect average effects of the flood, it suggests that 1997 and 1998 adult returns to some coastal basins will be reduced by the floods.

Population Trends and Production

Southern Oregon/Northern California Coasts ESU

New information received since the status review for the Oregon portion of this ESU includes updated abundance estimates (cited in the Population Abundance section above), harvest rate indices for coho salmon produced at Cole Rivers Hatchery on the upper Rogue River (discussed under ESU 3 below), and preliminary results of two population sustainability models (discussed under ESU 3 below).

Using terminal run size estimated at Huntley Park as a proxy for escapement and harvest rate index estimates (methods discussed under ESU 3 below) based on coded-wire tag (CWT) recoveries for Cole Rivers Hatchery fish, the BRT estimated both long-term (full available data series) and short-term (most recent 10 years) percent annual change in natural spawning escapement, ocean run size (calculated as escapement divided by 1 - harvest rate), and recruits per spawner (calculated as ocean run size divided by spawners 3 years earlier). Trend estimation methods were discussed in the status review. In estimating ocean run size, terminal sport harvest, which is commonly assumed to have been about 10% for coho salmon until the late 1980s, with recent reductions down to less than 1%, was not adjusted for. In addition, no stock-specific estimates of sport harvest rates were available, and excluding this information compensates somewhat for the bias in the CWT ocean exploitation indices. At present, only incomplete CWT returns for the 1995 return year are available, but preliminary data indicate that harvest rate was extremely low; the assumed 1995 harvest rate was assumed to be equal to the 0.2% rate estimated for 1994. The BRT did not attempt to adjust trends for the contribution of stray hatchery fish; sufficient data for such an adjustment are not available for these populations.

Trends in naturally produced coho salmon escapement (as indexed by terminal run size at Huntley Park), ocean run size, and recruits-per-spawner are illustrated in Figure 1, and summarized in Appendix Table 2. For both long- and short-term trends, escapement estimates increase, while recruitment and recruits-per-spawner estimates decrease. All three data series exhibit wide fluctuations, so none of the estimated trends are significantly different from zero. The dominance of hatchery fish in the terminal run combined with evidence that hatchery fish are straying in the upper basin (see Population Abundance above) suggests that these trend estimates may include some production from stray hatchery fish, thus overestimating the productivity of the natural population. This raises the question of sustainability of natural populations in the absence of the hatchery program. This issue was addressed by Becklin (1997), who suggested that hydrologic conditions in the Rogue River Basin will deteriorate in the near future, and concluded that "[i]f hatchery supplementation is not maintained at current or higher levels over the next 10-15 years, the Rogue's total Coho population will drop precipitously."

Based on preliminary 1996 data (S. Jacobs, op. cit.), estimated return ratios for 1996 are the highest on record, but this may be influenced by an underestimate of parental spawners. The 1993 natural run estimated at Huntley Park (174) is substantially below the count of natural fish at Gold Ray Dam (756). Assuming the dam count is accurate and some spawning occurred in lower tributaries, a more reasonable run estimate of about 1,000 adults in 1993 would result in a spawner-to-spawner ratio of about 5.8, which is more in line with recent values. It is interesting that since 1984 the return ratios exhibit a distinct 2-year cycle, alternating between relatively high and relatively low ratios.

Oregon Coast ESU

For the Oregon Coast ESU, in addition to updated information on abundance trends cited above, we have also received updated spawner indices (peak counts per mile and total adults per mile) for ODFW's standard survey segments (S. Jacobs, ODFW, Pers. comm., May 8, 1996), and indices of ocean exploitation for several coho salmon stocks, computed from ocean recoveries of CWT groups released on station from ODFW hatchery programs (Lewis 1996). The spawner survey index data were discussed in the status review. Regarding harvest rates, in the status review the BRT used the Oregon Production Index (OPI) harvest index, which is computed from catch and escapement data for all stocks in the OPI area (extreme southwest Washington through California). The CWT-based indices offer two potential advantages over the OPI index. First, they are direct estimates of exploitation rate with clear statistical properties, while the OPI index is an indirect calculation that depends on assumptions regarding migration patterns and is heavily influenced by the abundance and harvest of Columbia River hatchery stocks. Second, the CWT-based indices allow examination of geographic differences in harvest rates, which in turn allows finer geographic resolution in estimating recruitment and productivity of stocks. There are also disadvantages to using CWT-based indices. First, they are a biased estimate of true exploitation rate because of incomplete tag recoveries in freshwater, which leads to overestimating ocean harvest by an unknown factor. Second, the CWT indices represent only landed catch, and are not adjusted for non-landed catch. This introduces a bias the other direction (underestimating ocean harvest), and this bias would be greater in recent years when coho salmon harvest restrictions have increased the ratio of non-landed to landed harvest mortality. Third, CWT data are only available since the late 1970s or early 1980s, depending on the stock, while the OPI index is available back into the 1960s. Fourth, individual stocks sometimes have small sample sizes, which leads to wide fluctuations in estimated exploitation rates at an individual stock scale.

Despite these disadvantages, the BRT chose to accept ODFW's recommendation to use CWT-based indices (ODFW 1994, 1995a). To alleviate the fourth problem to some degree, the BRT averaged indices over broader geographic areas corresponding to Oregon's coho salmon Gene Conservation Groups (GCGs). Lewis (1996) provided a set of ocean exploitation indices for CWT releases from individual hatcheries based on the ratio of ocean recoveries/total recoveries; indices for all hatcheries within a given GCG were averaged. This provided four index series for the four Oregon coast coho salmon GCGs, three in this ESU and one in the Southern Oregon/Northern California Coasts ESU. Figure 3 compares these four indices to the OPI index. In general, the five indices exhibit similar patterns of change in exploitation rate. The three northern indices suggest higher exploitation rates than the OPI index, while the South Coast GCG (south of Cape Blanco) index is generally lower than the OPI index.

Using spawning escapement indices (peak counts per mile in standard spawner surveys) and harvest rate index estimates, the BRT estimated both long-term (full available data series) and short-term (most recent 10 years) percent annual change in natural spawning escapement, ocean run size (calculated as escapement divided by 1 - harvest rate), and recruits per spawner (calculated as ocean run size divided by spawners three years earlier). Trend estimation methods were discussed in the status review. In estimating ocean run size, the BRT did not adjust for terminal sport harvest, which is commonly assumed to have been about 10% for coho salmon until the late 1980s, with recent reductions down to less than 1%. The BRT had no stock-specific estimates of sport harvest rates, and excluding them compensates somewhat for the bias in the CWT ocean exploitation indices. The BRT also did not attempt to adjust trends for the contribution of stray hatchery fish; sufficient data for such an adjustment are not available for these populations.

Trend estimates are summarized in Appendix Table 2 for populations in major coastal basins and for aggregate GCGs. Data for the three GCGs are illustrated in Figures 4, 5, and 6. For all three measures (escapement, run size, and recruits-per-spawner), long term trend estimates are negative in all three GCGs. Recent escapement trend estimates are positive for the Umpqua and Mid/South Coast GCGs, but negative in the North/Mid Coast GCG. Recent trend estimates for recruitment and recruits-per-spawner are negative in all three GCGs, and exceed 12% annual decline in the two northern GCGs. While the SRS population estimate data series (used to estimate total abundance above) is not long enough to reliably estimate population trends, the 6 years of data do show an increase in escapement (Fig. 2) and decrease in recruitment (Fig. 7) in all three GCGs.

On the basis of preliminary 1996 data, we have updated recent average ESU-wide trends in escapement, production (recruitment), and return ratios. We do not have sufficient 1996 data to update trend estimates for individual basins or GCGs, which remain current through 1995 (Appendix Table 2). Pre-fishery recruitment was higher in 1996 than in either 1994 or 1995, but exhibits a fairly flat trend since 1990 (Fig. 7). To put these data in a longer term perspective, we can only look at ESU-wide averages based on Peak Index and AUC escapement indices (Fig. 8, 9). These show an increase in spawners up to levels of the mid-to-late 1980s, but much more moderate increases in recruitment. Recruitment remains only a small fraction (ca. 1/4) of average levels in the 1970s. An examination of return ratios shows that spawner-to-spawner ratios have remained above replacement since the 1990 brood year, as a result of higher productivity of the 1990 brood year and sharp reductions in harvest for the subsequent broods. Recruit-to-spawner ratios for the last three broods have been the lowest on record, except for 1988, and possibly 1984 (only for the AUC index with OPI-Index harvest estimates). The new data do not change the overall pattern of decline coupled with a periodic fluctuation in recruits-per-spawner. There has been a long-term pattern of peaks in recruits-per-spawner every 4-5 years, with the height of the peaks declining through time. This pattern of declining strong fluctuations does not appear to be reflected in patterns of smolt-to-adult survival of hatchery fish (data from Lewis 1996, Coronado-Hernandez 1995), and so may reflect changes in freshwater production.

Model-Based Assessments of Risk

Three models were used as part of the OCSRI Science Team process for assessing population status: a regression-based method by Schreck et al. (1996), a traditional population-viability approach by Chilcote (1996), and a habitat-based model by Nickelson and Lawson (1997). The first two were presented in draft form only in the preliminary draft OCSRI conservation plan (State of Oregon 1996). The Nickelson-Lawson model was also presented in that document, but ODFW has focused on further development of that model over the past 6 months, and a revised version was included in supporting documents for the current draft OCSRI Conservation Plan (State of Oregon 1997). A fourth model for assessing extinction risk of Oregon coastal coho salmon is being developed by M. Lynch (University of Oregon) and S. Schultz (University of Miami), but we have no results from this model.

Below, the methods, assumptions, and results of each of the three Science Team approaches are discussed, followed by a brief comparison.

1. **Schreck et al. graphical analysis**--"The basic premise of this approach is that when there is reason to believe that a Gene Conservation Group ... or ESU ... is nearing threatened or endangered status, we need to examine the hard data for decisions. We can not rely on output of models alone and have total security in our listing or delisting decisions." (Schreck et al. 1996, p. 1). The "graphical" analysis is based on trends in yield (pre-harvest abundance) calculated from spawning survey data adjusted for harvest. Both linear and exponential regressions were fitted to the data (yield vs. time) to identify trends in the data and major shifts in the trajectory of abundance.

General findings were (1) general population trends and changes in those trends, (2) the importance of nadirs (low-points) in population fluctuations in determining risk, and (3) the role of the amplitude of fluctuations above nadirs as an indicator of population growth capacity. Detailed analysis was provided only for the North Coast GCG. For this GCG, data indicate a strong decline in yield from 1950 to 1995, but not a steady linear or exponential decline. The relationship changed in the late 1970s and early 1980s, starting a steady, rapid decline in abundance. They also found that during the most recent 14 years, the GCG never experienced abundance even reaching the nadirs of former abundance, that a "classification for fish in this GCG as 'threatened' could be justified if this trend continues," and that it should be reclassified as endangered if abundance continues to decline. Visual inspection of data for the Umpqua and Coos/Coquille GCGs did not suggest similar problems.

2. **Chilcote Population Viability Analysis model**--Chilcote's model uses ODFW's time series of spawner counts for individual basins, in conjunction with harvest rate estimates and estimates of proportion of hatchery spawners, to estimate stock-recruit (SR) relationships for each basin. In each generation, spawners are estimated as the number of both naturally-produced and hatchery-produced adults spawning naturally within each basin, and recruits are the number of naturally-produced adults that would return the next generation in the absence of fisheries. The SR relationship is based on a Ricker curve, but with the addition of a depensatory term that reduces recruits at very low spawner abundance. Future populations are simulated by calculating future populations from present populations via the mean SR relationship adjusted for ocean survival (ranging from 1% to 4% in this analysis) and harvest rate (fixed at 10% for this analysis), plus a random error term with a distribution based on the residuals from the fitted SR relationship. Simulations were run for 10 generations (30 years), and 1,000 runs were made for each simulation to generate a probability distribution of future escapements. Extinction risk was estimated as the probability that a population would drop below 2 fish per mile (or a total of 100 fish in the population for the Rogue).

Results of the simulations indicated that at 1% ocean survival (similar to that observed during 1990-95), 6 of 12 populations had a greater than 50% chance of extinction in 10 generations, while only one (Yaquina) had less than a 5% extinction probability. At 3% ocean survival (approximately average for 1975-95), no populations had greater than 50% extinction probability, and only four (Nehalem, Wilson, Siletz, and Rogue) had greater than 5% extinction probability. Chilcote concluded that "[o]cean survivals that are less than 2% for a period greater than 6 years apparently pose considerable risk to these populations." Results for the Rogue suggest that this population has a high extinction probability at very low ocean survival, but ocean survival estimates for the Cole Rivers Hatchery stock indicate that this population has experienced better ocean conditions (3% to 6% survival) than those north of Cape Blanco (1% to 3% survival). Chilcote also examined the relationship between extinction probability and starting spawner abundance, and concluded that "when the number of spawners decreases below about 1/3 of full seeding the probability of quasi-extinction increases rapidly." He suggested that 1/3 full seeding be used as a protective level to prevent short-term risk of extinction.

3. **Nickelson-Lawson habitat-based life cycle model**--The model consists of two somewhat independent parts: A habitat (or "production") component and a population dynamics ("forward simulation") component. The first part uses freshwater habitat survey information to predict smolt capacity and average production as a function of spawner density for specific stream reaches within basins. The second part combines the habitat-based production function with interannual variation in freshwater and ocean survival, harvest rate information, and some small-population genetic and demographic risk factors to predict statistical distributions of future population abundance, from which some measures of risk can be derived.

The habitat component predicts smolt capacity and production for individual reaches within basins. It is based largely on the overwinter survival portion of ODFW's Habitat Limiting Factors Model (HLFM), an earlier version of which was published in 1992. Where winter survey data is available, HLFM was used directly to predict smolt potential. However, because ODFW has much more extensive data from summer habitat surveys than from winter surveys, over-winter smolt potential is estimated for most reaches via a regression relating predictions of winter smolt potential from HLFM to summer habitat characteristics (channel width, gradient, number of beaver dams, and percent pool area). Key assumptions in the habitat component include: 1) over-winter habitat is the primary bottleneck to freshwater production, 2) survival from egg to summer parr is 7% for all reaches at full seeding, and 3) empirical smolt potential and survival relationships derived from data for a subset of streams apply uniformly to all streams on the Oregon coast.

The dynamic component is a Monte Carlo simulation, making multiple runs of the model and randomly drawing values for variables in each run, thus producing a statistical distribution of outcomes. (Present model applications have used 1,000 replicate runs, each either 10 or 33 generations in length.) It begins with three parameters for each reach as estimated by the habitat component: maximum smolt capacity, average overwinter survival rate, and egg deposition needed to produce maximum smolts. These estimates are used directly for reaches with habitat survey data; for unsurveyed reaches, the model extrapolates by randomly assigning parameters from surveyed reaches within the same basin. Once the initial parameters are assigned for each reach, an initial population of spawners is assigned to each reach. This initial cohort in a single reach is then simulated through a number (currently 10 or 33) generations, with eggs, summer parr, smolts, and adults estimated sequentially in each generation. Some assumptions of the dynamic component are: 1) age-2 males (jacks) do not contribute to spawning and are not counted as adults, 2) strays redistribute uniformly across the basin but do not stray between basins, 3) parr-survival measurements from the 1960s and 1970s in the Alsea basin are applicable in other basins at the present time, 4) errors estimated in survival regressions adequately reflect true patterns of natural variation, 5) reaches included in habitat surveys are representative of conditions throughout the basin, 6) a single male can effectively fertilize eggs from any number of females, 7) wild fish have twice the ocean survival of hatchery fish, 8) variation in egg-to-parr, parr-to-smolt, and marine survival rates are independent of each other, and 9) (for the 33-generation simulations) historical patterns of variation in the Aleutian Low Pressure Index accurately reflect future variation in marine survival of coho salmon.

Two main types of results are generated by the model: predictions of habitat potential, and predictions of future population potential. In terms of habitat potential, the model predicts that potential production for the Oregon Coast ESU varies from 169,000 adults at 3% marine survival to 431,000 at 5% survival, with corresponding spawning escapement required to seed habitat of 126,000 (3% survival) and 235,000 (5% survival). For the Rogue basin, the model predicts production potential of 6,800 with 5,400 spawners at 3% marine survival, and 29,000 with 14,000 spawners at 5% marine survival. Simulation results were presented only for three basins (Tillamook, Yaquina, and Coos) summarized in terms of three measures: median ending population, probability of population decline, and "extinction risk" defined as the probability that the modeled population will drop below 50 spawners. The authors noted that their measure of extinction risk is not fully rigorous, and consider it "exploratory." General conclusions from the model regarding sustainability of Oregon coast coho were:

> Starting populations of 150 or more resulted in similar ending populations after 33 generations.
>
> The risk of extinction increased for starting populations less than 300-400.
>
> At starting populations of 50 and 100, probability of extinction was inversely related to habitat quality.

Probability of extinction was greater in the Yaquina basin than the two other basins because small starting populations were spread thinly across a greater number of reaches with good habitat.

There would be a substantial increase in risk of extinction in basins with poor habitat quality if habitat quality declines by 30-60% over the next century. (This would probably apply to the Tillamook, Nestucca, Coquille, and Rogue basins.)

Similar declines in habitat quality would have a much lesser effect on sustainability in other basins, but population size would decline.

Future population abundance will be heavily influenced by marine survival and exploitation rate.

Populations of Oregon coastal coho salmon have not lost their resiliency, but they may do so in basins with poor habitat if habitat quality continues to decline at the same rate as during the past century.

Commentary--It is difficult to compare such divergent approaches to population analysis, especially when two remain in early draft form. The Schreck et al. model is strictly empirical, with no attempt to explain trends or perform long-term predictions. In this, it is similar to the trend analysis we have used, although it only looks at recruitment, not spawners or return ratios. The Chilcote model is similar to a variety of statistical population viability analysis (PVA) models, and uses empirical population data to estimate parameters for a simple dynamic model that generates future abundance predictions. The Nickelson-Lawson model is the most complex and best developed of the three, and takes a synthetic approach to constructing dynamics from estimates of life-stage production functions from a wide variety of data sources, with no direct reference to population abundance time series. The Nickelson-Lawson model is also the only one of these models that has undergone peer review, but only a very early draft was reviewed.

The Nickelson-Lawson model represents a substantial effort to incorporate in a single model a variety of factors affecting coho salmon populations, including freshwater habitat heterogeneity, small population demography, small-population genetics, harvest, and climate variation. It is by far the most complete attempt to address in a single analysis the complexities of salmon metapopulation dynamics and risks to sustainability, and the only existing salmon dynamics model to directly use empirical data on freshwater habitat quality over a broad regional scale. Where assumptions had to be made, the authors were conservative (i.e. erring on the side of overestimating risk) in most cases.

However, the model suffers from several shortcomings, in part reflecting lack of information on important processes, but more largely as a result of the extremely short time frame in which the model was constructed. Some important factors (such as the genetic and ecological effects of hatchery production) are not included, and the inclusion of others (such as small population demography and genetics) is incomplete. To date, there has been only limited effort to validate the model or its components, and in particular there has been no attempt to compare results of the dynamic component with historical abundance data to check for biases in trend or variability, both of which are vital concerns if the model is to be used for assessing sustainability or extinction risk. The model is very complicated, and thus very difficult to fully test and evaluate in a short time frame. A more detailed evaluation of this model is presented in Wainwright (1997).

Oregon Coast Salmon Restoration Initiative

Oregon's Coastal Salmon Restoration Initiative (State of Oregon 1997) was "designed to restore salmon to a sustainable level at which they can again be a part of people's lives" (Sect. 1, p. 2). Although the plan is being initially developed with emphasis on coastal coho salmon, it expected to be expanded to other salmonids and eventually help to "conserve and restore functional elements of ecosystems that support fish, wildlife, and people" (Sect. 1, p. 2). The plan consists of four essential elements: 1) coordinated agency programs, 2) community-based action, 3) monitoring, and 4) appropriate corrective measures. These elements, taken together, form a comprehensive state plan of unprecedented scope.

Measures in the plan that were considered by the BRT are described in Section 13--State Agency Measures. Section 13 provides measures to be taken by all state agencies to address four areas of concern--water quality, physical habitat, water quantity, and fish management. For each issue, agencies identified factors for decline and developed objectives and management measures to address these factors. For the fourth area of concern, fish management, the plan identifies two "key parameters for restoring salmon populations"--fish management and predation. Under the key parameter of fish management, they identify the following eight factors for decline:

Harvest impacts to spawner escapement
Illegal salmon catch
Salmon bycatch
Ocean productivity
Loss of genetic adaptation of wild populations from interbreeding with genetically dissimilar, less fit hatchery fish
Competition with hatchery reared fish
Low density reproductive failure of wild populations, and
Reduced nutrients (carcass nutrient cycle) from depressed runs

For each factor for decline, the report 1) briefly summarizes the background and concerns for the factor, 2) provides biological objectives to address the factor, 3) lists actions and measures proposed to achieve each objective, 4) describes the monitoring strategy that will allow decision makers to objectively assess whether the resource is responding to the recovery program, and, 5) comments on the adequacy of the proposed measure(s) to address the area of concern.

Finally, Section 14--State Agency Workplans, provides the details of the activities that will be undertaken by each state agency during 1997 to implement the measures in the OCSRI. For each activity, this section provides the background, goals, objectives, responsibilities, results, future, finding, and 1997 work schedule.

Further discussion of the identified factors for decline and objectives and activities proposed to address harvest and hatchery management issues are discussed below.

OCSRI Harvest Proposal

Synopsis--The OCSRI Plan (State of Oregon 1997, Sect. 13, Ch. 4) contains several objectives and measures related to harvest. The most important of these are summarized below.

Objectives:

A. Manage harvest impacts to strive for attainment of the lowest level spawner rebuilding criteria (see below) by 2004 with good ocean survival or by 2040 with poor ocean survival.

B. Critically review and adjust escapement targets for Oregon coast natural (OCN) coho stocks to ensure they are adequate to fully rebuild sustainable levels of natural production that utilize available spawning and rearing habitat.

C. Develop and conduct future fisheries that don't interfere with restoration of wild stocks.

D. Minimize hook and release fishery impacts.

E. Improve pre-season coho salmon stock predictors and their assessment in pre-season models.

Implementation Measures:

1. Establish new escapement targets. New escapement targets have been defined at two levels (or "tiers") for four "sub-aggregates" of the Oregon Coast ESU. The lower target is 50% of the spawners needed to achieve production potential at 3% marine survival as estimated by the Nickelson-Lawson model; the upper target is 150% of the lower target

(i.e. 75% of spawners needed). Based on most recent model runs, spawner abundance criteria for the four sub-aggregates are provided in Table 5.

2. Restrict harvest impacts. The proposal continues the present fisheries management plan (FMP) restriction on total fishery impacts to less than 20%, but further specifies that total exploitation will not exceed 15%, or lower if escapement falls below current levels. ODFW has submitted a plan to PFMC to implement a new harvest regime based on stock abundance and projected marine survival. Essentially, this plan restricts total harvest impacts (ocean, terminal, and freshwater) for each sub-aggregate in any year to certain percentages based on abundance of parental spawners and predicted marine survival, and restricts ocean fisheries to achieve the total impact limit for the weakest sub-aggregate. This regime would be fully re-evaluated in the year 2000, when 10 years of stratified random sampling (SRS) spawner data will be available. Total fishery impacts range from ≤15% during low marine survival, to ≤35%, during both high marine survival and both parents achieving high objectives, and grandparents achieving low objective (Table 6).

Table 7 shows which management "tier" (row of the harvest matrix) the four stock components would be in for the 1997-1999 fisheries (based on 1994-1996 escapements). Because the two northern units (plus the Umpqua if it were a separate unit) are in the "low" category, it is clear that they will be controlling ocean harvest. We don't yet know which column (low, medium, or high marine survival) will apply in these years.

3. Trout fisheries. ODFW will manage trout fisheries in coastal basins to reduce ecological interactions and incidental harvest mortality on juvenile salmonids.

4. Selective fisheries. ODFW will fin-clip all Oregon hatchery coho beginning with the 1995 brood and will "explore opportunities" to implement selective ocean and terminal fisheries targeting hatchery stocks.

5. Research and monitoring. Several research and monitoring activities are proposed, including expanded SRS surveys, starting regular smolt surveys, monitoring wild coho ocean survival, evaluating hook and release mortality, and improving adult abundance forecasts.

Issues--The following points raise some issues that were considered in evaluating the effectiveness of the plan.

Escapement targets. The rebuilding criteria are essentially only 50% and 75% seeding of the best one-third of habitat potential on the coast, with no expected escapement to the other two-thirds of habitat potential. Only the lower (50%) criterion is mentioned in objective A.

There is an inconsistency between the stock components used here and ODFW's Gene Conservation Groups (GCGs). The main issue is that the South-Central component includes two GCGs (Umpqua and Mid/South Coast). In our status review,we found substantial genetic separation between stocks in the Umpqua and in the Mid/South Coast GCG, the basins are ecologically distinct, and population dynamics appear to be different between the GCGs. This distinction would not have a large effect on harvest, except that combining the two GCGs would allow higher terminal harvest in the immediate future on the Umpqua stocks because the combined unit is currently meeting the lower rebuilding criterion, while the Umpqua by itself would not meet the criterion.

Ocean harvest. This is only a 4-year (1997-2000 fisheries) interim proposal, and has no guarantees beyond 2000. Also, the proposal is only as good as our ability to estimate and control harvest impacts. When harvest rates are low, they are dominated by indirect mortality, which is poorly estimated. Target harvest impacts are not always met in practice; for example, the 1995 preseason target was 12%, but post-season harvest impact estimates range from 12% to 23%. To fully implement this proposal, effort needs to be focused on better estimates of indirect mortality and how indirect mortality is affected by management regulations. Further improvements in FRAM or similar methodology (which NMFS Fisheries Analysis and Monitoring Division is sponsoring) should help.

The harvest matrix requires forecasting marine survival, which is problematic. The current OCN abundance forecast method is based on only a few years of data, with a very limited range of ocean conditions. Substantial effort should go into finding the best predictors, and applying them conservatively. These problems are addressed in research and monitoring measures in the plan.

OCSRI Coastal Hatchery Program Proposal

Proposed measures--In the OCSRI plan, hatchery impacts on wild fish fall under two factors for decline identified in the "State Agency Measures, Fish Management" (Sect. 13, Ch. 4) section. These factors for decline are: 1) Loss of genetic adaptation of wild populations from interbreeding with genetically dissimilar, less fit hatchery fish, and 2) competition with hatchery reared fish. In order to address these factors, ODFW proposes the following objectives and actions:

A. Reduce the genetic risk to wild populations by reducing the percentage of hatchery fish to less than 10% of the total population spawning in the wild. Actions to implement this objective include 1) incorporation of wild fish into hatchery broodstocks (will consider temporary use of captive broodstock developed from wild juveniles if wild runs are insufficient); 2) reduce the percentage of hatchery fish spawning with wild fish through acclimation sites or altering release locations; 3) reduce the number of hatchery fish released from 6.4 million in 1990 to

2.3 million by 1998 (proposed 1997 releases are provided in Table 8), and 4) improve adult capture facilities at hatcheries and fish ladders.

B. Clearly describe the purpose and conduct of all coastal coho hatchery programs. ODFW will develop specific management objectives, including genetic guidelines, for each coastal coho hatchery program that 1) include the specific purpose of each program; 2) ensure consistency with sound genetic principles; and 3) evaluate the effectiveness and economic efficiency of the program.

C. Facilitate differentiation of hatchery fish from wild fish on spawning grounds. This will be accomplished by marking all hatchery coho smolts, and was begun with the 1995 brood (1998 return) coastwide and with the 1994 brood from the Trask Hatchery. Identifying and enumerating marked fish during annual spawning escapement surveys will provide a more precise estimate of wild:hatchery ratios than had been achieved through scale analysis. This will provide a better indication of the extent of hatchery fish spawning naturally and may lead to further modification of hatchery programs if significant numbers of hatchery fish continue to spawn naturally.

D. Reduce the potential for competition between juvenile hatchery and wild coho by decreasing the number of hatchery fish released. This will be accomplished by reducing coastal hatchery smolt releases from 6.4 million (1990) to 2.3 million (1998) (Table 8).

Hatcheries may be used to benefit wild fish under two additional factors for decline: 1) low density reproductive failure of wild populations, and 2) reduced nutrients (carcass nutrient cycle) from depressed runs. To address these factors, ODFW proposes to:

A. Evaluate the potential and effectiveness of using hatchery production to rebuild or restore critically depressed wild populations of coastal coho salmon. This plan will include 1) development of broad implementation strategies to utilize hatchery production to assist in rebuilding wild runs; 2) identification of locations where wild populations may be aided by hatchery fish and development of site specific implementation strategies prior to stocking; 3) monitoring and evaluation of stocking programs utilizing adaptive management approaches to evaluate and refine the program.

B. Increase the growth and survival of juvenile coho salmon in streams in which spawner abundance is depressed by increasing the abundance of adult salmon carcasses in spawning areas during and shortly after the spawning season. Hatchery spawner carcasses will be placed in test stream reaches that are not water quality limited, and monitored to detect effects on salmon and water quality, to determine the feasibility and effectiveness of the program.

SUMMARY AND CONCLUSIONS OF RISK ASSESSMENTS

The BRT considered important new information and analyses for several risk factors (hatchery production and genetic risks, habitat conditions, population abundance, and population trends and production) on a coastwide basis to allow comparison of specific factors across ESUs. The following section summarizes these factors for each ESU, and draws conclusions regarding the degree of extinction risk facing each ESU based on this new information as well as that in Weitkamp et al. (1995). The BRT evaluated extinction risk from two perspectives: 1) under the assumption that present conditions would continue into the future, and 2) assuming that hatchery and harvest reforms would be implemented as articulated in the OCSRI plan.

Approach to Risk Evaluation

The ESA (section 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." NMFS considers a variety of information in evaluating the level of risk faced by an ESU. Important considerations include 1) absolute numbers of fish and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and carrying capacity of the habitat; 3) trends in abundance, based on indices such as dam or redd counts or on estimates of spawner-recruit ratios; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., selective fisheries and interactions between hatchery and natural fish); and 6) recent events (e.g., a drought or a change in management) that have predictable short-term consequences for abundance of the ESU. Additional risk factors, such as disease prevalence or changes in life history traits, may also be considered in evaluating risk to populations. These considerations and approaches to evaluating them are described in more detail in Weitkamp et al. (1995).

According to the ESA, the determination whether a species is threatened or endangered should be made on the basis of the best scientific information available regarding its current status, after taking into consideration conservation measures that are proposed or are in place. In this review, we did not evaluate likely or possible effects of conservation measures (except some specific aspects of the OCSRI, as noted above). Therefore, we do not make recommendations as to whether identified ESUs should be listed as threatened or endangered species, because that determination requires evaluation of factors not considered by us. Rather, we have drawn scientific conclusions about the risk of extinction faced by identified ESUs under the assumption that present conditions will continue (recognizing, of course, that existing trends in factors affecting populations and natural demographic and environmental variability are inherent features of "present conditions").

In considering the status of the ESUs, we evaluated both qualitative and quantitative information. Qualitative evaluations included recent, published assessments by agencies or conservation groups of the status of coho salmon stocks within the geographic area. Quantitative evaluations included comparisons of current and historical abundance of coho salmon. Although this evaluation used the best data available, it should be recognized that there are a number of limitations to these data, and not all summary statistics were available for all populations. For example, spawner abundance was generally not measured directly; rather, it often had to be estimated from limited survey data. In many cases, there were also limited data to separate hatchery production from natural production.

Evaluation Under Present Conditions

Southern Oregon/Northern California Coasts ESU

Estimates of natural population abundance in this ESU continue to be based on very limited information. Favorable indicators include recent increases in abundance in the Rogue River and the presence of natural populations in both large and small basins, factors that may provide some buffer against extinction of the ESU. However, large hatchery programs in the two major basins (Rogue and Klamath/Trinity) raise serious concerns about effects on, and sustainability of, natural populations. For example, available information indicates that virtually all of the naturally spawning fish in the Trinity River are first generation hatchery fish. Several hatcheries in the California portion of this ESU have used exotic stocks extensively in the past, in contrast to Cole Rivers Hatchery in Oregon which has only released Rogue River stock into the Rogue River. New data on presence/absence in northern California streams that historically supported coho salmon are even more disturbing than earlier results, indicating that a smaller percentage of streams in this ESU contain coho salmon compared to the percentage presence in an earlier study. However, it is unclear whether these new data represent actual trends in local extinctions, or are biased by sampling effort.

In the Rogue River Basin, natural spawner abundance in 1996 was slightly above levels in 1994 and 1995. Abundances in the most recent 3 years are all substantially higher than abundances in 1989-1993, and are comparable to counts at Gold Ray Dam (upper Rogue) in the 1940s. Estimated return ratios for 1996 are the highest on record, but this may be influenced by an underestimate of parental spawners. The Rogue River run included an estimated 60% hatchery fish in 1996, comparable to recent years. The majority of these hatchery fish return to Cole Rivers Hatchery, but we have no estimate of the number that stray into natural habitat.

In summary, the new information did not substantially change the overall assessment of risk to this ESU, and the BRT concluded that the ESU is likely to become endangered in the foreseeable future. Most members felt that the degree of risk faced by this ESU was slightly less than that faced by the Central California Coast ESU. There was a strong concern about the lack of solid population data on which to base this decision.

Oregon Coast ESU

Since the original status review, escapement has been increasing for the ESU as a whole, but recruitment and recruits per spawner have remained low. Recruitment and escapement remain a small fraction of historical abundance. Spawning is distributed over a relatively large number of basins, both large and small. While recent natural escapement has been estimated to be on the order of 50,000 fish per year in this ESU, reaching nearly 80,000 fish in 1996, this has been coincident with drastic reductions in harvest. Pre-fishery recruitment was higher in 1996 than in either 1994 or 1995, but exhibits a fairly flat trend since 1990. The 1996 estimate of ESU-wide escapement indicates an approximately four-fold increase since 1990. When looked at on a finer geographic scale, the northern Oregon coast still has very poor escapement, the north-central coast is mixed with strong increases in some streams but continued very poor escapement in others, and the south/central coast continues to have increasing escapement.

Both recruitment and recruits-per-spawner have been declining rapidly (12% to 20% annual declines over the last 10 years) in two of the three ODFW Gene Conservation Groups (GCGs) in this ESU. These declines are steeper and more widespread in this ESU than in any other for which data are available, and recruits-per-spawner have continued to decline since this ESU was reviewed in 1994. Spawner-to-spawner ratios have remained above replacement since the 1990 brood year, as a result of higher productivity of the 1990 brood year and sharp reductions in harvest for the subsequent broods. Recruit-to-spawner ratios for the last three broods have been the lowest on record, except for 1988. The new data do not change the overall pattern of decline coupled with a periodic fluctuation in recruits-per-spawner. There has been a long-term pattern of peaks in recruits-per-spawner every 4-5 years, with the height of the peaks declining through time.

Risks that this decline in recruits per spawner pose to sustainability of natural populations, in combination with strong sensitivity to unpredictable ocean conditions. was the most serious concern identified by the BRT for this ESU. Some aspects of this concern can be addressed by examining results of the viability models, although none of them incorporates declining recruits per spawner except as a consequence of changing ocean conditions. Preliminary results of viability models provide a wide range of results, with one model suggesting that most Oregon coastal stocks cannot sustain themselves at ocean survivals that have been observed in the last 5 years, even in the absence of harvest, and another suggesting that stocks are highly resilient and would be at significant risk of extinction only if habitat degradation continues into the future. Consequently, a major question in evaluating extinction risk for this ESU is whether recent ocean and freshwater conditions will continue into the future.

For this ESU, fishery recruitment forecasts for 1997 are slightly below the actual 1996 recruitment (PFMC 1997b). These forecasts are based only on ocean conditions with no inclusion of parental stock size or variation in freshwater production. 1997 runs will be produced from 1994 escapement, which was relatively low, and this brood was affected by the 1995-96 floods on the coast. Stream production studies conducted by ODFW (Solazzi and Johnson 1996) indicate that 1996 smolt production in four central coast study streams was lower than recent averages, with overwinter survival the lowest or second lowest on record for the two streams for which estimates were made, and that age-0 fish production was also low. They conclude that the "most significant impact was on juvenile coho salmon eggs that were in the gravel at the time of the flood." While these results are based on a small sample of streams and may not reflect average effects of the flood, they suggest that 1997 and 1998 adult returns to some coastal basins will be reduced by the floods. Longer term effects of the floods can also be expected to vary among basins, but most reports available to us suggest that long-term effects should generally be neutral or slightly beneficial (e.g. from sediment removal and increased off-channel habitat) to coho salmon.

Widespread spawning by hatchery fish as indicated by scale data was also a major concern to the BRT. Scale analysis to determine hatchery-wild ratios of naturally spawning fish indicate moderate to high levels of hatchery fish spawning naturally in many basins on the Oregon coast, and at least a few hatchery fish were identified in almost every basin examined. Although it is possible that these data do not provide a representative picture of the extent of this problem, they represent the best information available at the present time. In addition to concerns for genetic and ecological interactions with wild fish, these data also suggest natural spawner abundance may be overestimated by ODFW and that the declines in recruits per spawner in many areas may have been even more alarming than current estimates indicate. However, Oregon has made some significant changes in its hatchery practices, such as substantially reducing production levels in some basins, switching to on-station smolt releases, and minimizing fry releases, and proposes additional changes (discussed below), to address this and other concerns about the impacts of hatchery fish on natural populations. Uncertainty regarding the true extent of hatchery influence on natural populations was a strong concern.

Another concern discussed by the BRT is the asymmetry in the distribution of natural spawning in this ESU, with a large fraction of the fish occurring in the southern portion and relatively few in northern drainages. Northern populations are also relatively worse off by almost every other measure: steeper declines in abundance and recruits-per-spawner, and higher proportion of naturally spawning hatchery fish. Habitat quality appears to be worse in the north coast than in the central coast, although some south coast basins (e.g. Coquille and Rogue) also have limited good quality habitat (Nickelson and Lawson 1997). Several members of the BRT felt that populations experiencing these poor conditions represent the majority of the geographic range and a substantial portion of the genetic diversity of the Oregon Coast ESU.

With respect to habitat, the BRT had two primary concerns: first, that the habitat capacity for coho salmon within this ESU has significantly decreased from historical levels; and second, that the Nickelson-Lawson model predicted that, during poor ocean survival, only high quality habitat is capable of sustaining coho populations, and subpopulations dependent on medium and low quality habitats would be likely to go extinct. Both of these concerns caused the BRT to consider risks from habitat loss and degradation to be relatively high for this ESU.

The BRT concluded that, assuming present conditions continue into the future (and that proposed harvest and hatchery reforms are not implemented), this ESU is not at significant short-term risk of extinction, but that it is likely to become endangered in the foreseeable future. A minority felt that the ESU is not likely to become endangered. Of those members who concluded that this ESU is likely to become endangered, several expressed the opinion that it was near the border between this and a "not at risk" category.

Evaluation with Hatchery and Harvest Reforms

The OCSRI Draft Conservation Plan (State of Oregon 1997) is a complex proposal with actions that could affect many factors posing risk to coastal coho salmon populations. The BRT considered only two sets of measures: harvest management reforms and hatchery management reforms. The BRT did not consider the likelihood that these measures will be implemented; rather, it only considered the likely consequences for ESU status if these measures were fully implemented as described.

The BRT also did not consider the potential effects of numerous measures in the Plan that may influence freshwater habitat conditions. Harvest and hatchery measures discussed here have quantifiable effects that can be reasonably related to population abundance and genetic integrity. This is much more difficult for habitat related measures. To effectively evaluate these measures would have required detailed information on factors limiting production, baseline conditions, and likely changes in conditions that would result from implementing the measures. Such information was not available to the BRT. Harvest and hatchery measures were also largely the same as those articulated in an earlier draft of the Plan (State of Oregon 1996), and more time was available to thoroughly evaluate them.

Our evaluations were based on descriptions of the harvest measures in Section 13, Chapter 4, p. 2-14 and descriptions of hatchery measures in Section 13, Chapter 4, p. 16-21. In order to carry out these evaluations, the BRT also made the following assumptions:

1) The ocean harvest management regime would be continued as proposed into the foreseeable future, not revised in the year 2000 as stated in the plan. Without this assumption, effects of the plan beyond 2000 could not be evaluated.

2) Hatchery releases would continue at or below 1997 release levels (including approximately 1 million annual fry releases) into the foreseeable future.

3) The goals of maintaining naturally-spawning hatchery fish at less than 10% or 50% of natural escapement (depending on genetic similarity with natural fish) will be achieved and demonstrated by effective monitoring.

The BRT had several concerns regarding both the harvest and hatchery components of the OCSRI plan. Some members had a strong concern that we do not know enough about the causes of declines in run size and recruits per spawner to be able to directly assess the effectiveness of specific management measures. Some felt that the harvest measures were the most encouraging part of the plan, representing a major change from previous management. However, there was concern that the harvest plan might be seriously weakened when it is re-evaluated in the year 2000, concern that combining the Umpqua and south/central coast GCGs into a larger aggregate (as would occur in the proposed harvest plan) might not adequately protect genetic diversity, and concern about our ability to effectively monitor non-target harvest mortality and to control overall harvest impacts.

Of the proposed hatchery measures, substantial reductions in smolt releases have the most predictable benefit for natural populations; all else being equal, fewer fish released should result in fewer genetic and ecological interactions with natural fish. Marking all hatchery fish should also help to resolve present uncertainties about the magnitude of these interactions. However, the BRT expressed concerns regarding some aspects of the proposed hatchery measures. The plan is vague on several key areas, including plans for incorporation of wild broodstock and how production will be distributed among facilities after 1997. The plan also suggests that the recent and proposed reductions are motivated largely by economic constraints and the inability at present to harvest fish even if they were produced. This results in a concern that if economic and harvest constraints change in the future, there may be pressure to resume larger programs. Other concerns expressed by the BRT included the lack of reductions in fry releases in many basins, substantially higher releases of smolts in the Yaquina River Basin (which by ODFW's own assessment has more high quality habitat than any other coastal basin), and no discussion of alternative culture methods that could be used to produce higher-quality hatchery smolts, which may have less impact on wild fish. Another concern was the plan's lack of recognition that, in addition to affecting fitness within populations, hatchery-wild interactions can reduce genetic diversity among populations.

Southern Oregon/Northern California Coasts ESU

Although the OCSRI proposals are directed specifically at the Oregon portion of this ESU, the harvest proposal would affect ocean harvest of all fish in this ESU as well. The proposed hatchery reforms can be expected to have a positive effect on the status of populations in the Rogue River Basin. However, the BRT concluded that these measures would not be sufficient to alter the previous conclusion that the ESU is likely to become endangered in the foreseeable future.

Oregon Coast ESU

The BRT generally agreed that implementation of the harvest and hatchery proposals would have a positive effect on the status of the ESU, but the BRT was about evenly split as to whether the effects would be substantial enough to move the ESU out of the "likely to become endangered" category. Some members felt that, in addition to the extinction buffer provided by the estimated 80,000 naturally produced spawners in 1996, the proposed reforms would promote higher escapements and alleviate genetic concerns enough that the ESU would not be at significant risk of extinction or endangerment. Other members saw little reason to expect that the hatchery and harvest reforms by themselves would be effective in reducing what they view as the most serious threat to this ESU--declining recruits per spawner. If the severe declines in recruits per spawner of natural populations in this ESU are partly a reflection of continuing habitat degradation, then risks to this ESU might remain high even with full implementation of the hatchery and harvest reforms. While harvest and hatchery reforms may substantially reduce short-term risk of extinction, habitat protection and restoration were viewed as key to ensuring long-term survival of the ESU, especially under variable and unpredictable future climate conditions.

HATCHERY POPULATIONS

If either the Southern Oregon/Northern California Coasts ESU or the Oregon Coast ESU are identified as threatened or endangered species in the final listing determination, it will be necessary for NMFS to determine the ESA status of hatchery populations that are associated with the listed ESU(s). According to NMFS policy (Hard et al. 1992), two key questions must be addressed for each hatchery stock associated with a listed species: 1) Is it part of the ESU? and, if so, 2) Should the hatchery population be listed? The focus of these evaluations should be on "existing hatchery fish," which are defined in the policy to include prespawning adults, eggs, or juveniles held in a facility, as well as fish that were released prior to the listing but have not completed their life cycle.

The first question--the ESU status of existing hatchery populations--is a biological one, and the guiding principle should be whether the hatchery population contains genetic resources similar to those of natural populations in the ESU. The second question is an administrative one. According to NMFS policy, existing hatchery fish would generally not be listed even if they are part of the ESU unless they are considered "essential" for recovery.

To address the ESU question, the BRT considered information on stock histories and broodstock collection methods for existing hatchery populations associated with the two ESUs, summarized in Appendix A. In evaluating importance for recovery, the BRT considered the relationship between the natural and hatchery populations and the degree of risk faced by the natural population(s) the hatchery stock might be used to assist in recovery. Hatchery programs that have not recently produced coho salmon were not considered.

It is important to note two things with respect to the evaluations of hatchery populations. First, the BRT conclusions apply to individual hatchery stocks and not to facilities. Stock numbers for Oregon hatchery stocks are included in parentheses to allow identification of the stocks in question. Second, a determination that a stock is not "essential" for recovery does not preclude it from playing a role in recovery. Any hatchery population that is part of the ESU is available for use in recovery if conditions warrant. In this context, an "essential" hatchery population is one that is vital to fully incorporate into recovery efforts at the outset (for example, if the associated natural population(s) were already extinct or at high risk of extinction). Under these circumstances, NMFS would consider taking the administrative action of listing the existing hatchery fish at the time of the final listing determination. In any case, fish that are progeny of listed fish taken into a hatchery for broodstock will be listed, so any hatchery population involved in formal recovery under the ESA will eventually be comprised of listed fish.

Southern Oregon/Northern California Coasts ESU

Hatchery populations that should be considered part of the ESU

Mattole River
Eel River
Trinity River
Rowdy Creek
Rogue River

Hatchery populations that are not part of the ESU

Mad River

Hatchery populations of uncertain ESU status

Iron Gate

Overall, the BRT concluded that most hatchery populations in this ESU should be considered part of the ESU. This included populations that are only sporadically produced and therefore use primarily wild fish as brood stock, and those with a history of past use of out-of-basin and out-of-state stocks and/or relatively long histories of domestication. However, the BRT concluded that Mad River Hatchery stock, because of the use of numerous exotic stocks including recent releases of out-of-ESU stocks, had sufficiently diverged from natural coho salmon in the ESU that it was no longer part of the ESU. There was also considerable uncertainty within the BRT whether the use of non-native stocks to start the Iron Gate Hatchery population had lasting effects on the present population.

Importance for recovery

The BRT did not consider any of these populations essential for recovery, given currently available information. However, two stocks were identified that may play a particularly important role in recovery efforts: Mattole River (because the natural population is very depressed) and Trinity River (because there appears to be essentially no natural production in the basin).

Oregon Coast ESU

Hatchery populations that should be considered part of the ESU

Coos River (37)
Coquille River (44)
Cow Creek (18)
North Umpqua River (55)
Tahkenitch/Siltcoos (105)
Alsea River and tributaries (43)
Salmon River (36)
Fishhawk Creek (99)

Hatchery populations that are not part of the ESU

Fall Creek (31)
Siletz River (33)
Trask River (34)

Hatchery populations of uncertain ESU status

North Fork Nehalem River (32)

The BRT concluded that all of the recently-derived Oregon coast hatchery populations, most of which continue to incorporate natural fish into the broodstock each generation, were clearly part of the BRT. The BRT also included the Salmon River population in this group due to its relatively short period of domestication and genetic similarity to the recently-derived stocks. The BRT decided that most of the older hatchery stocks had diverged from natural fish to the point that they were no longer part of the ESU. This decision was based largely on the length of domestication of these stocks, and their genetic dissimilarity to either natural fish or the recently-derived hatchery populations. There was considerable uncertainty within the BRT whether the North Fork Nehalem River population was sufficiently different from natural fish that it no longer represented the ESU.

Importance for recovery

The BRT did not identify any of these populations as essential for recovery, but recognized that some of them (e.g., Alsea River) might become important part of recovery efforts.

REFERENCES

Anderson, D. M. 1996. Letter to M. Schiewe dated July 26, 1996. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Anonymous. 1995a. Review comments: Status review of coho salmon from Washington, Oregon, and California by USDC - NOAA - NMFS. Memo to Steve Stone, NMFS, Portland, OR. Nov. 6, 1995. 3 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Anonymous. 1995b. Review of Weitkamp et al. (1995): Status review of coho salmon from Washington, Oregon, and California. Letter to Garth Griffin, NMFS Portland, OR. Nov. 1, 1995. 5 p. + attachments. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Becklin, D. M. 1997. Letter to William M. Stelle, Jr., January 15, 1997, re. Rogue River coho salmon and steelhead. 1 p. + attachments. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Beechie, T., E. Beamer, and L. Wasserman. 1994. Estimating coho salmon rearing habitat and smolt production losses in a large river basin, and implications for habitat restoration. N. Am. J. Fish. Manage. 14(4):797-811.

Borgerson, L. A. 1991. Scale analysis. Oreg. Dep. Fish Wildl., Annual Prog. Rep., Fish Res. Proj. F-144-R-2, 32 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Borgerson, L. A. 1992. Scale analysis. Oreg. Dep. Fish Wildl., Annual Prog. Rep., Fish Res. Proj. F-144-R-4, 22 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Borgerson, L. A. 1997. FAX to L. Weitkamp with preliminary scale analysis results. Dated 5 March 1997, 4 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Brown, L. R., P. B. Moyle, and R. M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. N. Am. J. Fish. Manage. 14:237-261.

Bush, G., C. McConnell, C. Cloyd, K. Musser, and B. Metzer. 1997. Assessment of the effects of the 1996 flood on the Siuslaw National Forest. Siuslaw Natl. Forest, Draft Tech. Rep. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

California Department of Fish and Game. 1995. Letter from Douglas Wheeler to Garth Griffin. Oct. 28, 1995, + attachment. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Chilcote, M. 1996. A population viability assessment of coho salmon in Oregon based upon spawner-recruit data from 13 populations. Oregon Department of Fish and Wildlife, Portland. 11 p. (Attachment II, Appendix 2 to the Draft OCSRI Plan, dated 8/16/96.) (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Confer, T. 1996. General comments regarding coho salmon distribution and abundance in the South Coast and Lower Rogue Management District. Oregon Department of Fish and Wildlife, Portland. (Attachment II-B-III.C to the Draft OCSRI Plan, dated 8/20/96.)

Coronado-Hernandez, M. C. 1995. Spatial and temporal factors affecting survival of hatchery-reared chinook, coho, and steelhead in the Pacific Northwest. Ph.D. Dissertation, University of Washington. 235 p.

Dahl, T. E. 1990. Wetlands losses in the United States 1780's to 1980's. U.S. Dep. Interior, Fish and Wildl. Serv., Washington, D.C.

Dewberry, C., P. Burns, and L. Hood. 1996. The effects of the storms of 1996 on anadromous fish-bearing reaches in the Knowles Creek Watershed. Draft Report for John Hancock Timber Management Group, 15 p. + tables. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Edwards, R., G. Portes, and F. Fleming. 1992. Regional nonpoint source program summary. Env.. Prot. Agency, Region 10, Seattle, WA.

Fisk, L., E. Gerstung, and J. Thomas. 1966. Stream damage surveys-1966. Calif. Dep. Fish and Game, Inland Fish. Div., Administrative Rep. 66-10., 15 p.

Forest Ecosystem Management Assessment Team (FEMAT). 1993. Forest ecosystem management: an ecological, economic, and social assessment. USDA and five other federal agencies.

Foy, M. G., C. Huntington, J. Big Eagle, C. R. Steward, and K. K. English. 1995. Coho salmon catch, escapement and historical abundance data. Report to USDC, NOAA, NMFS. May 1, 1995. 52 p. + appendices. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Gregory, S. V., and P. A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. *In* D. J. Stouder, P. A. Bisson, and R. J. Naiman (editors), Pacific salmon and their ecosystems: Status and future options, p. 277-314. Chapman and Hall, New York,

Hard, J. J., R. P. Jones, M. R. Delarm, and R. S. Waples. 1992. Pacific salmon and artificial propagation under the Endangered Species Act. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWFSC-2, 56 p.

Jacobs, S. E. 1988. Straying in Oregon by adult salmon of hatchery origin, 1985. Oreg. Dep. Fish Wildl. Info Rep. 88-5, 53 p.

Jacobs, S. E. 1996. SRS estimates of Oregon coastal coho spawner abundance and enclosed scale and CWT summaries from Tom Nickelson. Memo to T. Wainwright, NMFS, NWFSC, dated May 14, 1996. 6 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Jacobs, S. E., and C. X. Cooney. 1991. Improvement of methods used to estimate the spawning of Oregon coastal natural coho salmon. Oreg. Dep. Fish Wildl., Fish Div. Prog. Rep. 1991, 24 p.

Jacobs, S. E., and C. X. Cooney. 1992. Improvement of methods used to estimate the spawning escapement of Oregon coastal natural coho salmon. Oreg. Dep. Fish Wildl., Fish Div. Prog. Rep. 1992, 23 p.

Jacobs, S. E., and C. X. Cooney. 1993. Improvement of methods used to estimate the spawning escapement of Oregon coastal natural coho salmon. Oreg. Dep. Fish Wildl., Fish Div. Prog. Rep. 1993, 28 p.

Kellogg, E., (editor). 1992. Coastal temperate rain forests: ecological characteristics, status, and distribution worldwide. Ecotrust and Conservation International, Portland, OR and Washington, D.C.

Kreissman, B. 1991. California, an environmental atlas and guide. Bear Klaw Press, Davis, CA.

Lewis, M. 1995. Stock assessment of anadromous salmonids. Oregon Department of Fish and Wildlife, Fish Division, Progress Reports 1995. 103 p.

Lewis, M. 1996. Letter to T. Wainwright dated May 23, 1996. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Lichatowich, J. A. 1989. Habitat alteration and changes in abundance of coho (*Oncorhynchus kisutch*) and chinook salmon (*O. tshawytscha*) in Oregon's coastal streams. *In* C. D. Levings, L. B. Holtby, and M. A. Anderson (editors), Proceedings of the national workshop on effects of habitat alteration on salmonid stocks, p. 92-99. Can. Spec. Publ. Fish. Aquat. Sci. 105.

McHenry, M. L. 1996. Freshwater habitat conditions affecting Strait of Juan de Fuca populations of coho salmon (*Oncorhynchus kisutch*). Lower Elwha Klallam Tribe, Port Angeles, Washington, 46 p.

Moore, K. and K. Jones. 1997. Assessment of 1996 flood impacts: Channel morphology and fish habitat. Oreg. Dep. Fish Wildl., Research Sect., Draft Report, 16 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Murphy, M. L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska--requirements for protection and restoration. U.S. Dep. Commer., NOAA Coastal Ocean Office, Silver Spring, MD, 156 p.

National Marine Fisheries Service (NMFS). 1991. Notice of policy: Policy on applying the definition of species under the Endangered Species Act to Pacific salmon. Federal Register [Docket 910248-1255, 20 November 1991] 56(224):58612-58618.

National Marine Fisheries Service (NMFS). 1993. Listing endangered and threatened species and designating critical habitat: Petition to list five stocks of Oregon coho salmon. Federal Register [Docket 93-26365, 27 October 1993] 58(206):57770-57771.

National Marine Fisheries Service (NMFS). 1996a. Factors for decline: A supplement to the notice of determination for West Coast Steelhead under the Endangered Species Act. NMFS, Protected Species Branch, Portland, Oregon, 83 p.

National Marine Fisheries Service (NMFS). 1996b. Supplemental report of the Biological Review Team on central California coast coho salmon. Memorandum from M. Schiewe to W. Stelle, dated 17 October, 1996, 4 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Natural Resources Consultants, Inc (NRC). 1995. Database of artificially propagated anadromous salmon (database). Prepared for NMFS Conservation Biology Program, Coastal Zone and Estuarine Studies Division, Northwest Fisheries Science Center, Contract No. 50ABNF400128.

Nickelson, T. 1996. 1996 Status update for Oregon coho salmon. Research and Development Section, Oregon Department of Fish and Wildlife, Corvallis. 6 p. + figures. (Attachment II-B-II to the Draft OCSRI Plan dated 8/20/96.) (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Nickelson, T. and S. Jacobs. 1996. Recent hatchery/wild analyses from scales and comparison of hatchery and wild run timing. FAX to Laurie Weitkamp, NMFS, NWFSC, Oct. 7, 1996. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Nickelson, T., and P. Lawson. 1996. Application of a habitat-based life cycle model to the question of sustainability of Oregon coastal coho salmon: a working draft. Research and Development Section, Oregon Department of Fish and Wildlife, Corvallis. 16 p. (Attachment II, Appendix 1 to the Draft OCSRI Plan dated 8/21/96.) (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Nickelson, T. E., and P. W. Lawson. 1997. Population dynamics of Oregon coastal coho salmon: Application of a habitat-based life cycle model. Attachment A to Sect. 13, Ch. 4 in State of Oregon (1997). (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Nickelson, T. E., J. D. Rodgers, S. L. Johnson, and M. F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Can. J. Fish. Aquat. Sci. 49:783-789.

Norse, E. A. 1990. Ancient forests of the Pacific Northwest. The Wilderness Society and Inland Press, Washington, D.C.

Oregon Department of Fish and Wildlife (ODFW). 1994. Status Assessment Talking Points: NMFS preliminary consideration to list all Oregon Coho salmon as threatened. Fax to NMFS Northwest Region. Dec. 19, 1994. 7 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Oregon Department of Fish and Wildlife (ODFW). 1995a. Oregon coho salmon biological status assessment and staff conclusion for listing under the Oregon Endangered Species Act. Oregon Department of Fish and Wildlife, Portland, February 22 1995. 59 p. (Attachment II-B-I to the Draft OCSRI Plan dated 8/20/96.)

Oregon Department of Fish and Wildlife (ODFW). 1995b. Letter from Douglas DeHart to Garth Griffin. Oct. 20, 1995. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Oregon Department of Fish and Wildlife (ODFW). 1996. Fish Propagation Program, Oregon Department of Fish and Wildlife. Materials provided by R. Berry to S. Smith and L. Weitkamp, 16 August 1996. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Oregon Coastal Salmon Restoration Initiative (OCSRI) Science Team. 1996b. Recommendations related to population status. Draft report dated 8/21/96. 11 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Pacific Fisheries Management Council (PFMC). 1996. Review of 1995 ocean salmon fisheries. Pacific Fishery Management Council, Portland OR. Feb. 1996. 106 p + appendices.

PFMC. 1997a. Review of 1996 ocean salmon fisheries. Pacific Fishery Management Council, Portland, Oregon, February 1997.

PFMC. 1997b. Preseason report I: Stock abundance analysis for 1997 ocean salmon fisheries. Pacific Fishery Management Council, Portland, Oregon, February 1997. 43 p. + appendices.

Pacific Watershed Associates. Undated. Post-storm aerial reconnaissance of the middle Oregon Cascades and middle Coast Range. Preliminary executive summary, 5 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Reeves, G. H., F. H. Everest, and T. E. Nickelson. 1989. Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. U.S. Dep. Agric. Forest Serv., Pac. Northwest. Res. Stn., Portland, Oregon, 18 p.

Satterthwaite, T. 1996. General comments regarding coho salmon in the Rogue Basin. Oregon Department of Fish and Wildlife, Portland. (Attachment II-B-III.A to the Draft OCSRI Plan dated 8/20/96.) (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Schmitt, C., J. Schweigert, and T. P. Quinn. 1994. Anthropogenic influences on fish populations of the Georgia Basin. *In* R. C. H. Wilson, R. J. Beamish, F. Aitkens, and J. Bell (editors), Review of the marine Environment and biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait., p. 218-229.

Schreck, C., with P. Harris and M. Fitzpatrick. 1996. Oregon coastal coho salmon listing and delisting criteria base on graphical analysis of long-term trends. Appendix 3 of Attachment II in State of Oregon (1996). (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Sedell, J. R., and J. L. Froggatt. 1984. Importance of streamside forests to large rivers: the isolation of the Willamette River, Oregon, U.S.A., from its floodplain by snagging and streamside forest removal. Verh. Internat. Verein. Limnol. 22:1828-1834.

Sedell, J. R., and K. J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. . *In* N. B. Armantrout (editor), Acquisition and utilization of aquatic habitat inventory information., p. 210-222.

Simenstad, C. A., K. L. Fresh, and E. O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: an unappreciated function. *In* V. S. Kennedy (editor), Estuarine comparisons, p. 343-364. Academic Press, Toronto.

Siuslaw National Forest. 1996. '96 Floods. A workshop on watershed restoration presented by Siuslaw National Forest, Feb. 4, 1997--Corvallis Public Library, 7 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Solazzi, M. F., and S. L. Johnson. 1996. Development and evaluation of techniques to rehabilitate Oregon's wild salmonids. Oregon Department of Fish and Wildlife, Fish Division, Progress Reports. 10 p.

Speis, T. A., and J. F. Franklin. 1988. Old growth and forest dynamics in the Douglas-fir region of western Oregon and Washington. Natural Areas J. 8:190-201.

State of Oregon. 1996. Draft OCSRI Plan. Salem, Oregon, August 1996. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

State of Oregon. 1997. The Oregon Plan: Oregon's Coastal Salmon Restoration Initiative. Salem, Oregon. (Submitted to National Marine Fisheries Service on March 10, 1997). (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

U.S. Fish and Wildlife Service. 1996. Trinity River flow evaluation. Administrative review draft report, U.S. Fish and Wildlife Service, Ecological Services, Sacramento Field Office, p. 29.

U.S. Forest Service and U.S. Bureau of Land Management. 1996. Storms and floods of the winter of 1995-96. USDA Forest Service Pacific Northwest Region and Pacific Northwest Forest and Range experiment station and USDI BLM Oregon state office.

Vogt, J. 1996. General comments regarding coho salmon distribution and abundance in the Upper Rogue Management District. Oregon Department of Fish and Wildlife, Portland. (Attachment II-B-III.B to the Draft OCSRI Plan dated 8/20/96.) (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

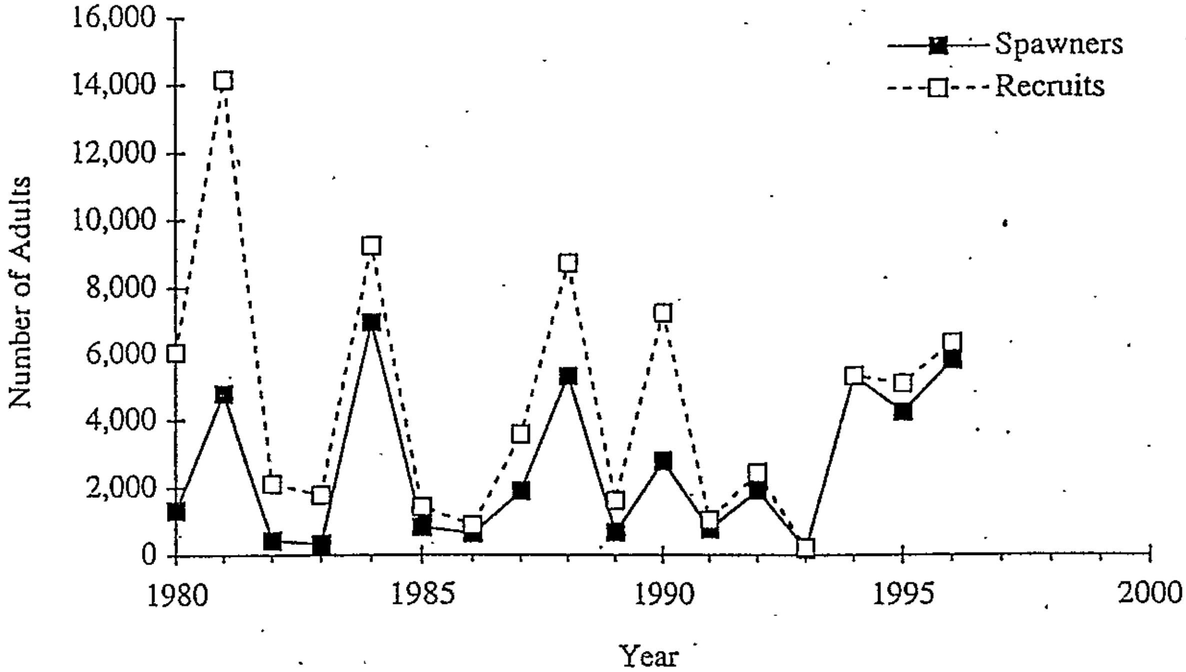
Wainwright, T. 1997. ODFW coho sustainability model. Memo to M. Schiewe, 6 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Waples, R. S. 1991. Pacific salmon, *Oncorhynchus* spp., and the definition of "species" under the Endangered Species Act. U.S. Natl. Mar. Fish. Serv. Mar. Fish. Rev. 53(3):11-22.

Washington Department of Fish and Wildlife (WDFW). 1995. Letter from Robert Turner to Garth Griffin. Nov. 1, 1995. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Washington Department of Fisheries (WDF), Washington Department of Wildlife (WDW), and Western Washington Treaty Indian Tribes (WWTIT). 1993. 1992 Washington State salmon and steelhead stock inventory (SASSI). Wash. Dep. Fish Wildl., Olympia, WA, 212 p. + appendices.

Weitkamp, L. A., T. C. Wainwright, G. J. Bryant, G. B. Milner, D. J. Teel, R. G. Kope, and R. S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. NOAA Tech. Memo. NMFS-NWFSC-24. 258 p.



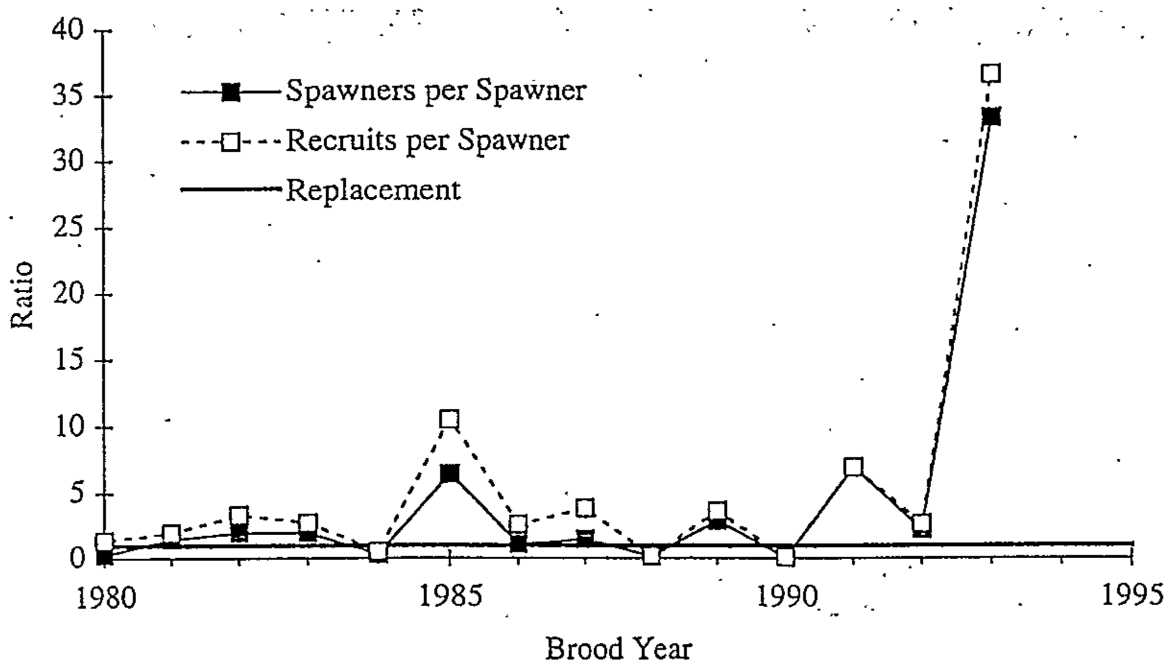


Figure 1. Estimated abundance (upper panel) and returns per spawner (lower panel) of naturally-produced Rogue River coho salmon adult spawners and ocean recruits. Estimates based on expansion of seine-net samples at Huntley Park (T. Nickelson, ODFW, pers. comm. 15 May 1996; S. Jacobs, ODFW, pers. comm. 27 February 1997).

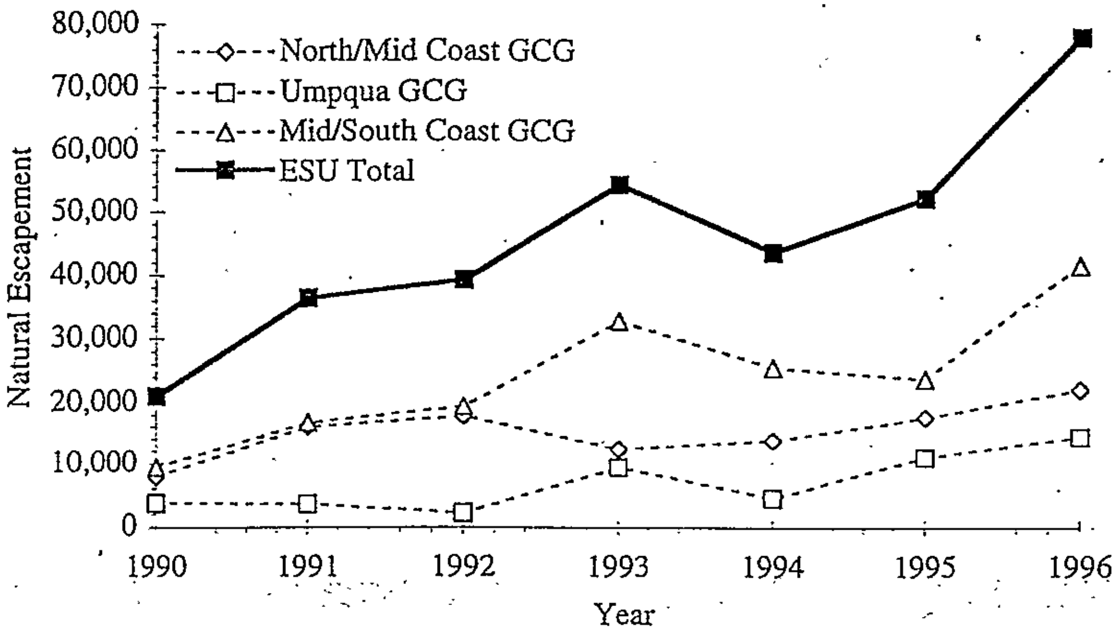


Figure 2. Estimated total adult escapement of coho salmon in the Oregon Coast ESU, based on stratified random survey information (Nickelson 1996, S. Jacobs, ODFW, pers. comm. 27 February 1997)

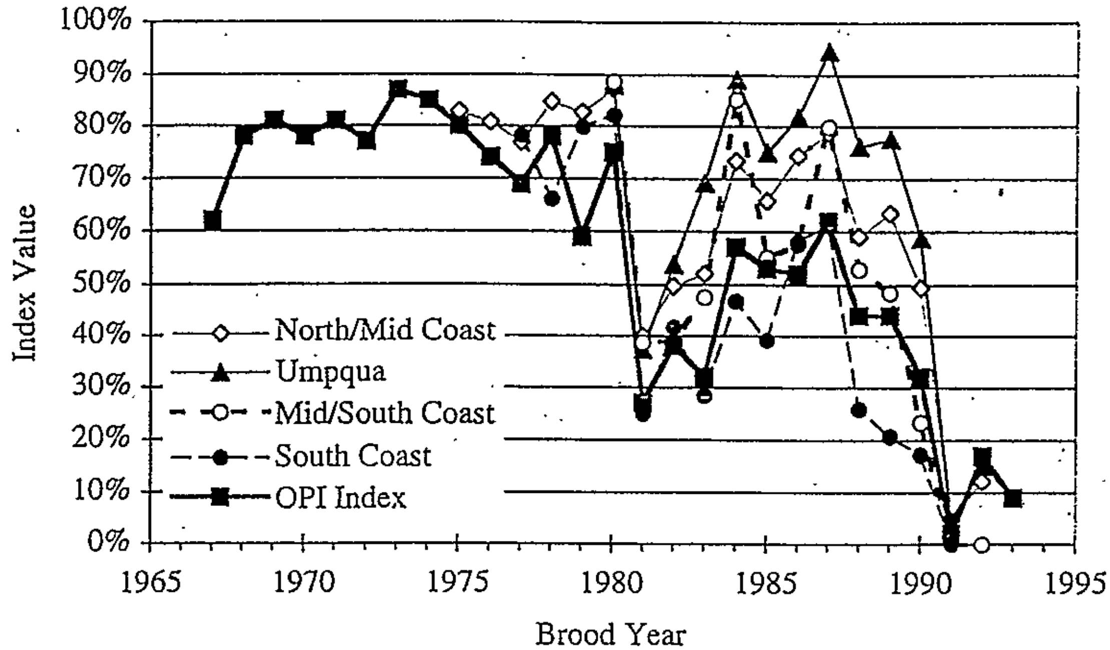
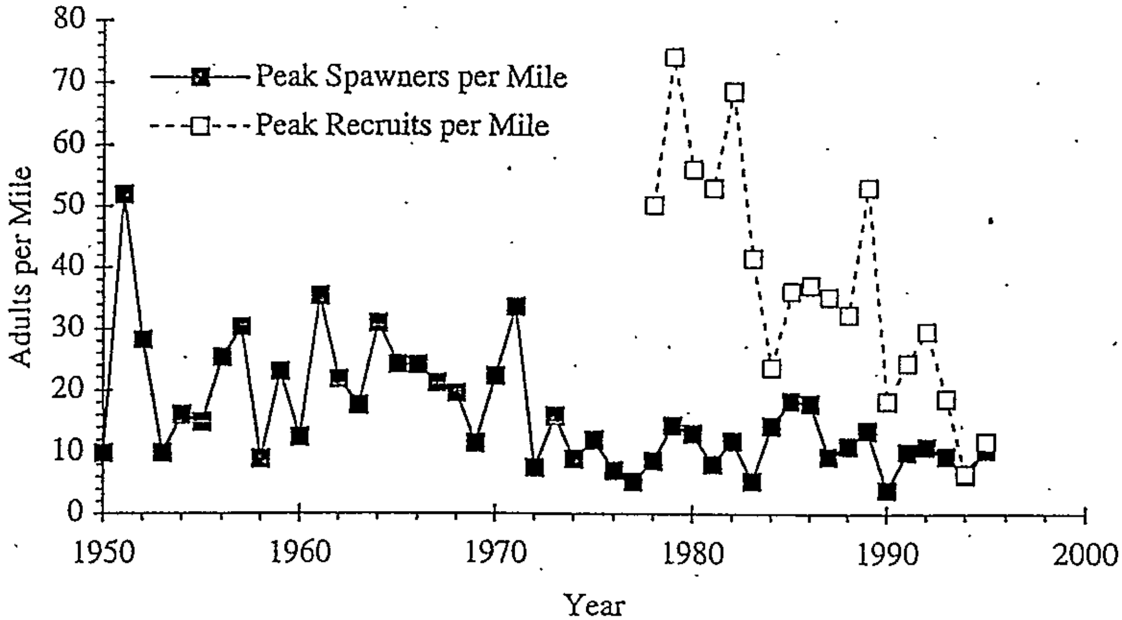


Figure 3. Ocean exploitation indices estimated for four Oregon coast gene conservation groups from coded-wire tag data for Oregon coast hatcheries (Lewis 1996), compared with the OPI index (PFMC 1997).



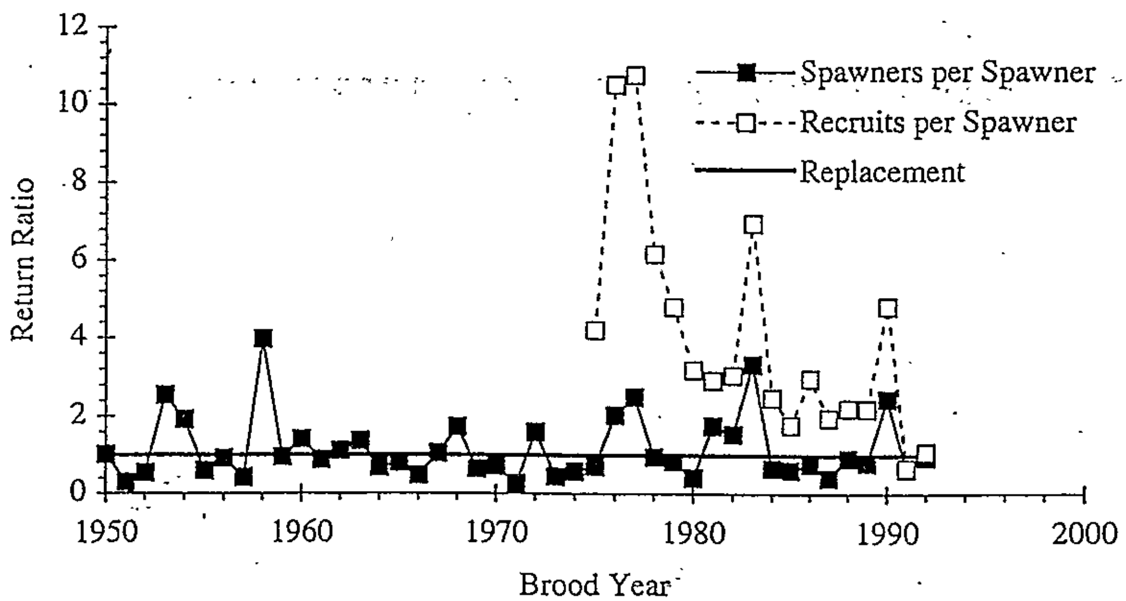
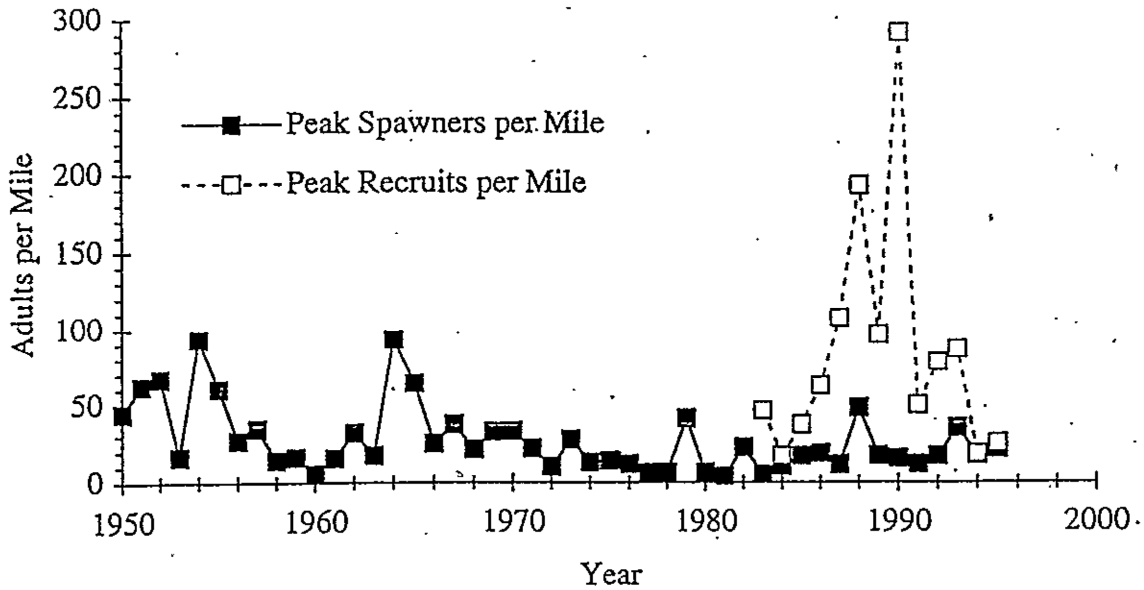


Figure 4. Estimated abundance (upper panel) and returns per spawner (lower panel) of coho salmon adult spawners and ocean recruits in the North/Mid Coast Gene Conservation Group. Estimates based on peak counts in standard survey segments (S. Jacobs, ODFW, pers. comm. 8 May 1996).



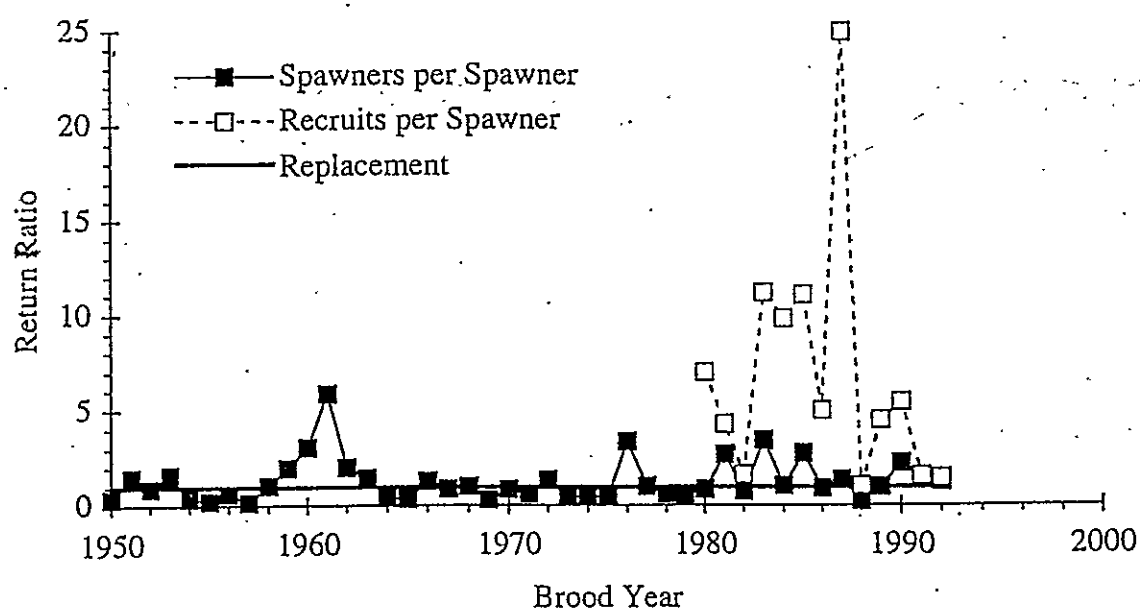


Figure 5. Estimated abundance (upper panel) and returns per spawner (lower panel) of coho salmon adult spawners and ocean recruits in the Umpqua Gene Conservation Group. Estimates based on peak counts in standard survey segments (S. Jacobs, ODFW, pers. comm. 8 May 1996).

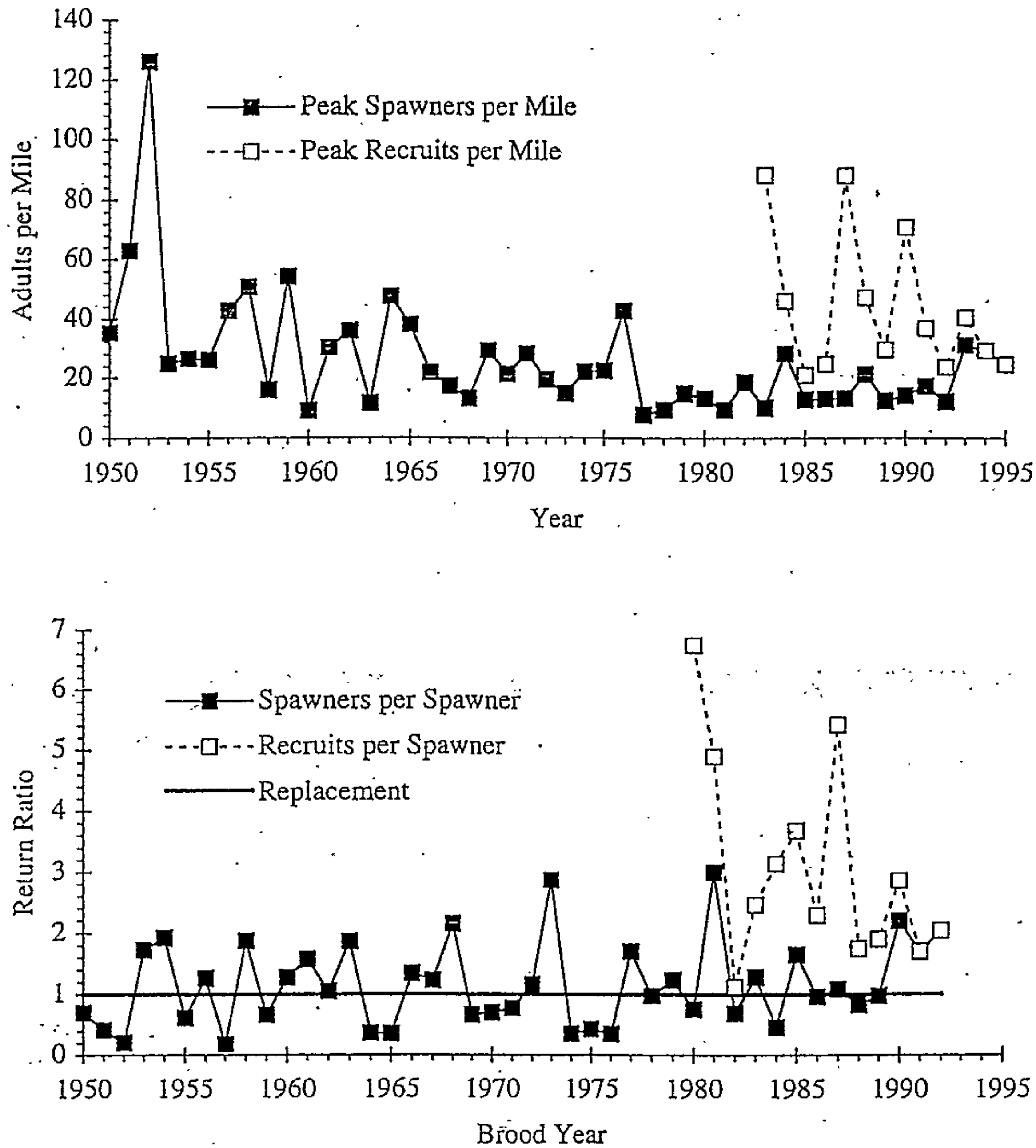


Figure 6. Estimated abundance (upper panel) and returns per spawner (lower panel) of coho salmon adult spawners and ocean recruits in the Mid/South Coast Gene Conservation Group. Estimates based on peak counts in standard survey segments (S. Jacobs, ODFW, pers. comm. 8 May 1996).

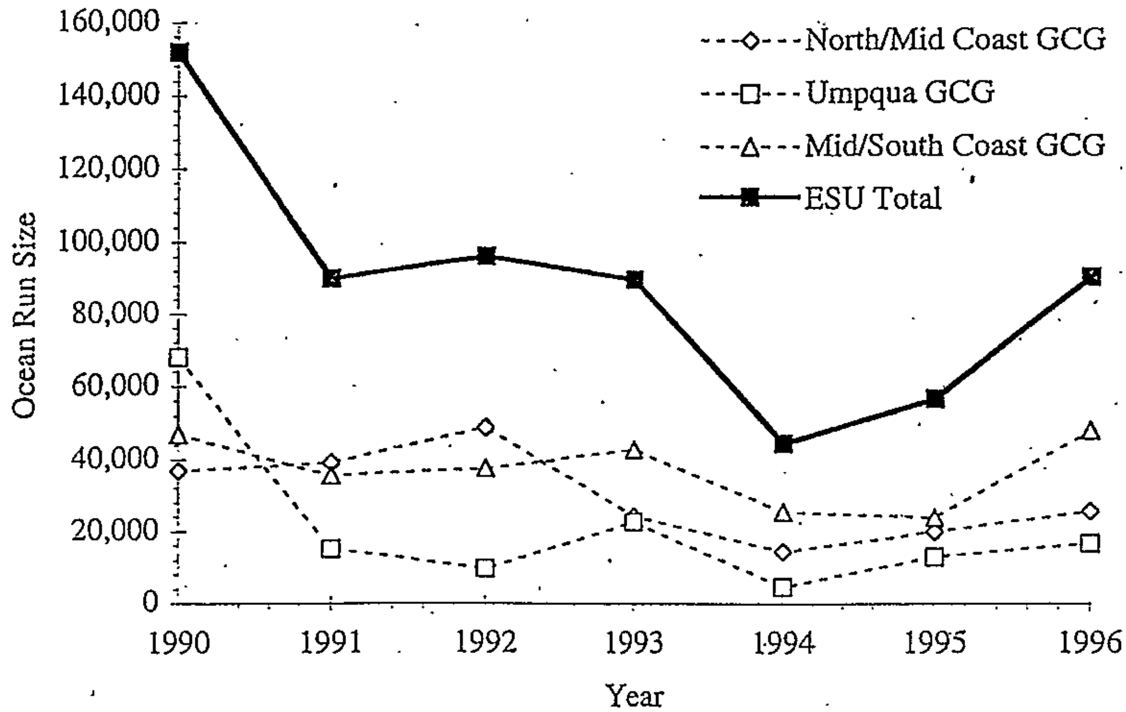


Figure 7. Estimated total ocean run size of coho salmon in the Oregon Coast ESU, based on stratified random survey information (Nickelson 1996, S. Jacobs, ODFW, pers. comm. 27 February 1997). Note that 1996 expansion from escapement is based on OPI harvest index (PFMC 1997), not CWT index as for other years.

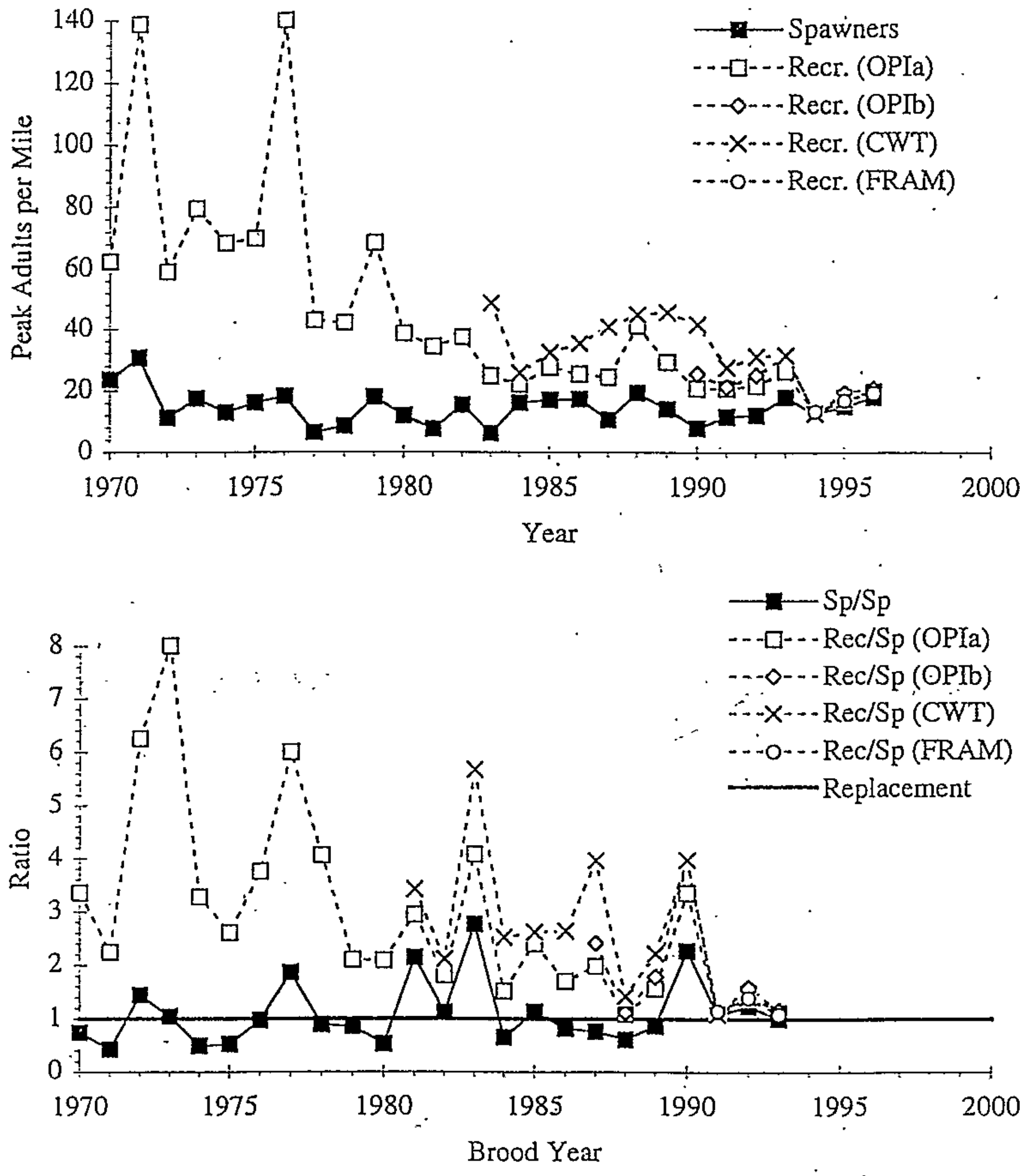
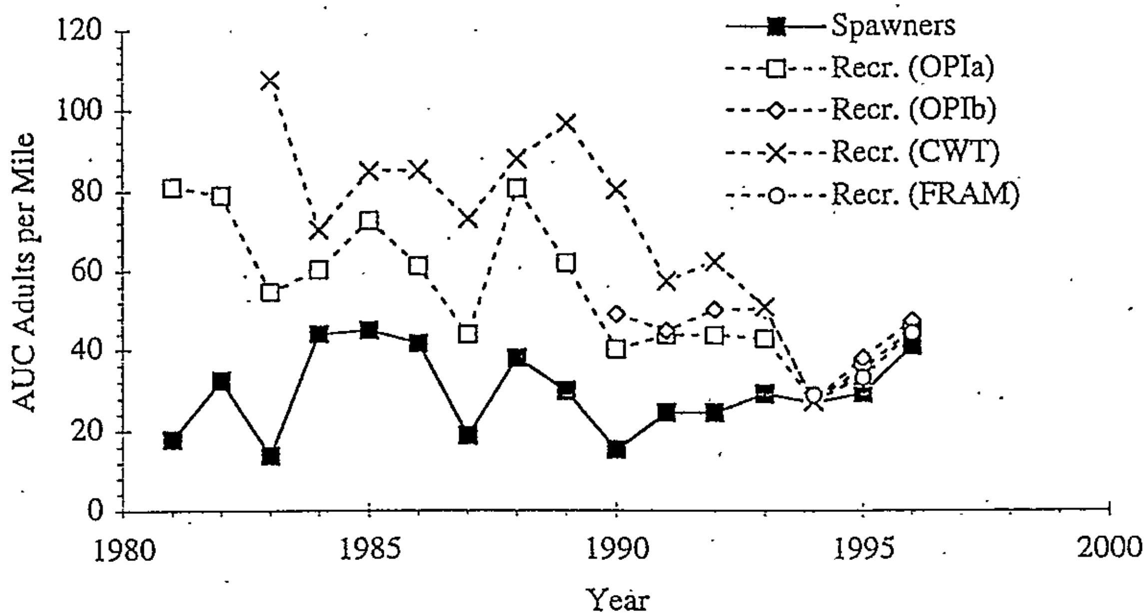


Figure 8. Estimated abundance (upper panel) and returns per spawner (lower panel) of coho salmon adult spawners and ocean recruits in the Oregon Coast ESU. Estimates based on peak counts in standard survey segments (S. Jacobs, ODFW, pers. comm. 27 February 1997), and four harvest rate indices (see text).



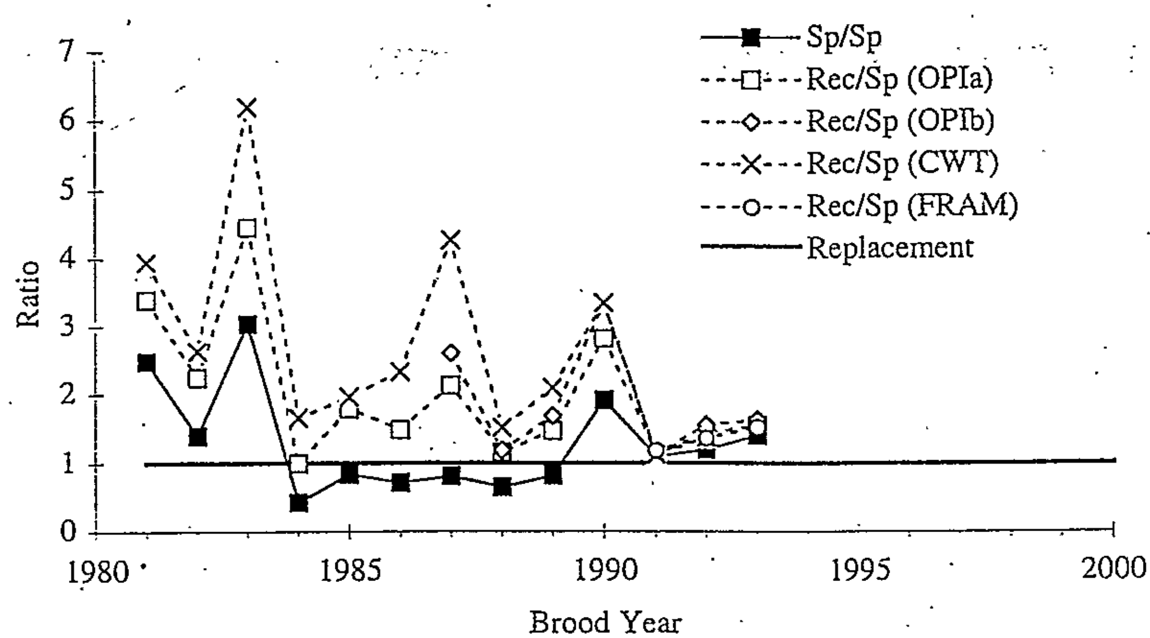


Figure 9. Estimated abundance (upper panel) and returns per spawner (lower panel) of coho salmon adult spawners and ocean recruits in the Oregon Coast ESU. Estimates based on area-under-the-curve estimates in standard survey segments (S. Jacobs, ODFW, pers. comm. 27 February 1997), and four harvest rate indices (see text).

Table 1. Comparison of data compiled by NMFS and ODFW and preliminary 1996 data on origin (hatchery or natural) of naturally spawning coho salmon based on scale analysis. NMFS estimate compiled from Borgerson 1991, 1992; Jacobs 1996. ODFW estimate provided by Nickelson and Jacobs 1996. Preliminary 1996 data from Borgerson (1997).

		NMFS Estimate (1989-95)			ODFW Estimate (1992-95)			1996 preliminary results	
			% H[a]						
Basin	Subbasin	*N*	unweigh.	weighted	*N*	% H[a]	Comm.[b]	*N*	% H[a]
Necanicum		34	42	38	17	53		3	0
Ecola/Elk Cr.		8	44	25				2	0
Arch Cape Cr.		4	50	50					
Nehalem	Mainstem	169	35	37	32	47	a	5	0
	N. Nehalem	466	89	89	115	92	b	17	100
	Rock Cr.				5	0			
Tillamook Bay	Kilchis	20	59	65	3	33	c	4	0
	Miami	5	56	60				1	0
	Tillamook	15	69	53	8	50	d	6	33
	Trask	333	81	89	60	85	b	16	50
	Wilson	27	38	22	6	17	c	16	13
Sand Lake		3	33	33	3	33			
Nestucca		37	27	14	22	9		4	50
Neskowin		1	100	100	1	100		3	0
Salmon		656	79	88	44	93	b	292	96
Devils Lake		36	12	14	6	17		1	0
Siletz	Mainstem	160	61	54				3	100
	Rock Cr.	124	79	73				1	100
	Schooner Cr. Trap	25	96	96					
	Drift Cr.							4	25
	All				30	43	c	8	63
Yaquina		226	21	17	13	8	c	125	64
Beaver Cr.		18	0	0	6	0		20	20
Alsea	Mainstem	31	47	65	26	69	b	2	0
	Drift Cr.	110	8	7	21	10		3	33
	Five Rivers	145	17	6	27	0	c	11	9
	N & S Forks							7	29
Yachats		19	43	32	5	20		10	40
Sutton Lake					6	17	e		

Table 1. Continued.

Basin	Subbasin	NMFS Estimate (1989-95)			ODFW Estimate (1992-95)			1996 preliminary results	
			% H[a]						
		N	unweigh.	weighted	*N*	% H[a]	Comm.[b]	*N*	% H[a]
Siuslaw	Mainstem	*91*	17	14	*10*	40	d	*10*	20
	N. Siuslaw	*13*	4	8	*4*	0	c	*8*	0
	Lake Cr.	*263*	40	56	*50*	40	f	*24*	42
	Wolf Cr.				*2*	0		*2*	0
Siltcoos		*331*	8	3				*70*	1
Tahkenitch		*569*	5	1				*113*	0
Umpqua	Mainstem	*99*	16	8	*13*	8		*26*	85
	Smith	*335*	4	2	*154*	1		*6*	0
	Elk Cr.	*49*	0	0	*16*	0		*5*	0
	S. Umpqua	*129*	35	35	*53*	23	c	*27*	41
Tenmile		*169*	0	1				*43*	0
Coos	Mainstem	*216*	23	10	*22*	9		*58*	0
	Millicoma	*185*	6	5	*134*	3		*13*	0
	S. Coos	*335*	11	5	*298*	3		*50*	0
Coquille	Mainstem	*29*	54	14				*3*	0
	N. Coquille	*202*	9	3	*49*	2		*67*	0
	E. Coquille	*54*	15	11	*11*	9		*13*	15
	M. Coquille	*70*	7	6	*42*	0	c	*9*	0
	S. Coquille	*26*	20	15	*9*	22	d	*8*	0
New R/Floras Cr.		*41*	14	22				*29*	3

[a] "% H" indicates the percentage of fish that were identified as of hatchery origin based on scale patterns. The NMFS "% H" values were calculated in two ways. The *unweighted* value is the percentage of all fish that were of hatchery origin, independant of the year collected, while the *weighted* value is the average (over all years) of the percentage of fish there were of hatchery origin in each year.

[b] ODFW comments were as follows:

- a 12 samples from Fishhawk Lake, difficult to ID
- b Site of Hatchery
- c Higher percentage wild than NMFS estimate
- d Lower percentage wild than NMFS estimate
- e Lake in system, identification problems?
- f 17 hatchery-classified samples from vicinity of hatchery smolt releases.

Table 2. Coho salmon releases from Oregon hatchery that were substantially different in 1995 compared to previous years. Data from NRC (1995) and ODFW (1996).

	Smolt releases	
Hatchery/Basin	1995	1990-94 Avg.
Trask (incl. Trask Ponds)	217,000	1,092,000
Salmon	316,000	374,000
Siletz	262,000	825,000
Yaquina	306,000	0

Table 3. Summary statistics of historical and current presence-absence data for coho salmon from the California portion of the Southern Oregon/Northern California Coasts ESU. Historical data were taken from the literature and current data determined from surveys conducted by NMFS Southwest Fisheries Science Center (P. Adams, Pers. comm., Aug. 27, 1996). Presence data from Brown et al. (1994) are also included for comparison.

Area	Streams historically inhabited by coho salmon	Streams recently surveyed	Number of streams[1] with coho salmon present	Percent of streams with coho salmon present	
				New data	Brown et al. (1994)
Del Norte County	130	46	21	46	55
Humboldt County	234	130	71	55	69
Total	364	176	92	52	63

[1] Refers to those streams recently surveyed.

Table 4. Population size of coastal coho spawners in geographic areas of the Oregon coast north of Cape Blanco in 1990-1996, plus 5-year (1992-96) geometric mean (GM), based on stratified random sampling spawner surveys (Jacobs and Cooney 1991, 1992, 1993). Data from S. Jacobs (pers. comm. 20 February 1997) and State of Oregon (1997).

Group	1990	1991	1992	1993	1994	1995	1996	5-yr GM
Mid- to North Coast GCG								
Necanicum-Nehalem	1,743	5,315	1,453	3,207	2,777	1,775	1,825	2,111
Tillamook-Nestucca	455	3,967	969	1,303	1,315	2,194	1,530	1,410
Salmon-Alsea	2,419	2,964	11,552	2,884	6,413	7,181	8,588	6,667
Yachats-Siuslaw	3,173	3,791	3,820	4,895	3,300	6,437	10,191	5,266
Umpqua GCG								
Umpqua	3,737	3,600	2,153	9,311	4,485	11,021	14,413	6,776
Mid- to South Coast GCG								
Lakes	4,414	7,283	1,585	10,145	5,841	11,216	13,500	6,770
Coos-Coquille	4,985	9,464	17,741	22,688	19,617	12,563	28,297	19,483
Total	**20,926**	**36,384**	**39,273**	**54,433**	**43,748**	**52,385**	**78,343**	**52,098**

Table 5. OCSRI proposed escapement targets for the four harvest-management sub-aggregates for spawners needed to achieve 50% and 75% of production potentials. From State of Oregon 1997, Section 13, Ch. 4, Table 3 (p. 6).

Sub-aggregate	Spawners needed to achieve: 50% of potential	75% of potential
Necanicum - Neskowin	10,700	16,100
Salmon - Siuslaw	28,500	42,800
Siltcoos - Sixes	24,400	36,700
Elk - Winchuck	2,700*	4,100*

*--Indexed to estimated Rogue River abundance from Huntley Park surveys.

Table 6. OCSRI proposed total allowable harvest impacts (ocean, terminal, and freshwater) for each sub-aggregate based on abundance of parental spawners and predicted marine survival. From State of Oregon 1997, Section 13, Ch. 4, Table 2 (p. 4).

	Marine Survival		
Parent Spawning Escapement:	**Low** (like 1994-1996)	**Medium** (like 1978-1985)	**High** (like 1972-74, 1976, 1986)
High (parents achieved high objective, and grandparents achieved low objective)	≤15%	≤30%	≤35%
Medium (parents achieved low objective)	≤15%	≤20%	≤25%
Low (parents below low objective)	≤15%*	≤15%	≤15%

*--10-13% for status quo conditions and parental escapement well below lowest criterion

Table 7. The management "tier" (row of the harvest matrix) each stock component would be in for the 1997-1999 fisheries under the proposed harvest regime (Table 7), based on 1994-1996 escapements. Based on Table 5 and data from State of Oregon 1997, Section 6, Table 1 (p. 2).

	Year of fisheries		
Sub-aggregate	1997	1998	1999
Necanicum - Neskowin	low	low	low
Salmon - Siuslaw	low	low	low
Siltcoos - Sixes	med	med	high
Elk - Winchuck	med	med	med

Table 8. Recent and proposed releases of coho salmon into selected Oregon coast basins. Data from NRC 1995, ODFW 1996.

Basin	1986-95 total avg.	1997 smolts	1997 fry	1997 total
Chetco	0			
Pistol	0			
Rogue	290,000	200,000	17,500	217,500
Elk	0			
New/Floras	0		20,000	20,000
Coquille	445,400	125,000	275,000	400,000
Coos*	413,700	55,000	205,000	260,000
Tenmile	449,700			
Umpqua	880,800	140,000	400,000	540,000
Tahkenitch	200			
Siltcoos	0			
Siuslaw	94,000		50,000	50,000
Yachats	0			
Alsea	1,320,100	400,000	540	400,540
Beaver Cr.	0			
Yaquina*	30,600	600,000	3,890	603,890
Depoe Cr.			36,000	36,000
Siletz	976,400	50,000	2,080	52,080
Devils Lake	0			
Salmon	795,000	100,000		100,000
Neskowin Cr.	0			
Nestucca	57,900			
Sand Lake	0			
Tillamook	7,000			
Trask	1,377,300	200,000	60,400	260,400
Wilson	0			
Kilchis	0			
Miami	0			
Nehalem	963,600	200,000	200	200,200
Ecola Cr.	0			
Necanicum	0			
Totals	8,101,700	2,070,000	1,070,610	3,140,610

* Does not include releases from commercial facilities.

Appendix Table 1. Summary of key risk factors associated with artificial production of coho salmon for selected river basins. Data from Borgerson 1991, 1992; Brown et al. 1994; NRC 1995; ODFW 1996; Jacobs 1996; USFWS 1996.

Basin	Hatchery in basin?[a]	1950-1985 No. stocks[b] tot (nat)	1950-1985 No. fish planted (1,000s)	1950-1985 % native[b]	1950-1985 % smolts	Post 1985[c] No. stocks[b] tot (nat)	Post 1985[c] No. fish planted (1,000s)	Post 1985[c] % native[b]	Post 1985[c] % smolts	Total nat. spawner abund. (recent)[d]	Estim. habitat[e] (linear miles)	Percent hatchery[f]	N[g]	Wild/. hatch. spawn timing overlap[h]
Oregon Coast ESU														
New/Floras	N	5(1)	2,553	28	9	0	0			1,500	38	14	41	--
Coquille	Y	4(1)	4,818	41	7	1(1)	4,454	100	23	4,200	333.5	7-20	381	high
Coos	Y[i]	10(1)	5,808	55	29	1(1)	4,137	100	15	7,410	224	6-23	736	high
Coos Commercial		15(3)	32,204	9	48	4(1)	6,047	75	100					--
Tenmile	N	6(2)	2,991	22	14	3(2)	4,497	98	22	3,350	69	<1	169	--
Umpqua	Y	6(2)	5,591	96	64	2(2)	8,808	100	45	5,670	1178	0-35	612	high
Tahkenitch	N	3(0)	341	<1	<1	1(1)	2	100	100	1,040	22	5	569	--
Siltcoos	N	1(0)	50	<1	<1	0	0			2,400	50	8	331	--
Siuslaw	N	6(0)	16,229	<1	1	6(1)	940	2	45	4,000	515	4-40	367	--
Yachats	N	1(0)	37	<1	<1	0	0			200	44	43	19	--
Alsea	Y	10(2)	31,381	76	67	2(2)	13,201	100	81	2,150	223	8-47	286	mod.
Beaver Cr.	N	4(0)	393	<1	34	0	0			320	19	<1	18	--
Yaquina	Y[i]	7(1)	1,201	4	14	1(0)	306	<1	100	1,500	113	21	226	--
Yaquina Commercial		17(2)	81,922	69	8	4(2)	22,787	67	1					--
Siletz	Y[i]	8(1)	19,240	83	65	3(1)	9,764	98	80	1,020	191	61-79	309	high
Devils Lake	N	7(0)	2,756	<1	<1	0	0			100	7	12	36	--
Salmon	Y	1(1)	1,897	100	84	1(1)	7,950	100	48	220	42	79	656	high
Neskowin Cr.	N	1(0)	19	<1	<1	0	0			50	16	100	1	--
Sand Lake	N	0	0			0	0			40	11	33	3	--
Nestucca	Y[i]	5(1)	2,223	6	38	2(1)	579	26	53	520	168	27	37	mod.
Tillamook	N	3(0)	726	<1	40	1(0)	70	<1	<1	180	47	69	15	--
Trask	Y	2(1)	31,063	100	50	1(1)	13,773	100	80	230	62	81	333	mod.
Wilson	N	2(0)	2,084	<1	42	0	0			270	71	38	27	--
Kilchis	N	1(0)	1,038	<1	53	0	0			160	43	59	20	--
Miami	N	4(0)	1,130	<1	49	0	0			70	19	56	5	--
Nehalem	Y	5(2)	22,420	89	72	2(2)	9,636	100	78	2,200	385	35-89	635	low
Ecola Cr.	N	0	0			0	0			50	8	44	8	--
Necanicum	N	2(0)	1,137	<1	56	0	0			500	52	42	34	--

Appendix Table 1. Continued.

Basin	Hatchery in basin?[a]	1950-1985 No. stocks[b] tot (nat)	No. fish planted (1,000s)	% native[b]	% smolts	Post 1985[c] No. stocks[b] tot (nat)	No. fish planted (1,000s)	% native[b]	% smolts	Total nat. spawner abund. (recent)[d]	Estim. habitat[e] (linear miles)	Percent hatchery[f]	N[g]	Wild/ hatch. spawn timing overlap[h]
Southern Oregon/Northern California Coasts ESU														
Mattole	N	0	0			1(1)	22	100	60	760	187	?		high?
Bear	N	1(0)	51	<1	<1	0	0					?		high?
Eel	N	7(1)	1,067	5	82	5(2)	55	13	5	2,040	894	?		high?
Elk	N	4(0)	280	<1	100	0	0					?		high?
Freshwater Cr	Y	2(0)	254	<1	45	2(1)	268	99	96			?		high?
Mad	Y	10(1)	3,665	21	69	4(1)	1,466	22	99	460	84	?		high?
Redwood Cr	Y	3(1)	76	14	100	1(1)	65	100	69	280	110	high		high?
Klamath	Y	9(2)	16,184	80	50	5(3)	7,540	100	88	1,860	813	?-100		high?
Smith	Y	6(0)	780	<1	84	1(1)	36	100	89	820	348	?		high?
Winchuck	N	0	0			0	0					?		high?
Chetco	N	4(0)	78	<1	36	0	0				32.7	?		high?
Pistol	N	0	0			0	0				17.6	?		high?
Rogue	Y	7(1)	2,147	84	61	2(1)	2,900	100	69	2,500	518	?	0	?
Elk	N	0	0			0	0				8.1	?		

[a] Includes egg-taking stations.

[b] Number in parenthesis indicates number of "native" stocks released (those whose name is the same as the basin name or a stream in the basin).

[c] These value represent releases through 1995 for all facilities except California Cooperative hatcheries.

[d] Reflects naturally spawning fish only; abundance estimates since 1985.

[e] For California basins, this value is salmon-accessible miles of habitat, estimated in the 1960s (CDFG 1965). For Oregon basins, this is current miles of spawning habitat

[f] When ranges are given, these reflect the highest and lowest values from various subbasins within the basin. Values do not include 1996 returns.

[g] Number of fish sampled for scales or marks to determine the percent of natural spawners that are of hatchery origin.

[h] Overlap of spawning timing between wild and hatchery fish is considered "high" if the peak timings substantially overlap, "moderate" if several weeks separate the two timings, and "low" if over a month separates the timings.

[i] Facility no longer in operation or no longer producing coho salmon.

Appendix Table 2. Summary of recent status information for west coast coho salmon stocks. Blanks indicate insufficient data. Stocks in italics represent aggregates of those below them. Based on data from T. Nickelson (pers. comm., 15 May 1996), Nickelson (1996), Lewis (1996), PFMC (1996), and S. Jacobs (pers. comm., 8 May 1996).

ESU	Recent abundance (5-yr geom. mean)		Recent Trends (most recent 10 yr)							Long-Term Trends (all years with complete data)								
Basin/Stock	Escape-ment	Run Size	Data Years	Escapement		Run Size		Recruits-per-Spawner		Escapement			Run Size			Recruits-per-Spawner		
				% a.c.	(s.e.)	% a.c.	(s.e.)	% a.c.	(s.e.)	Years	% a.c.	(s.e.)	Years	% a.c.	(s.e.)	Years	% a.c.	(s.e.)
Oregon Coast	44,553	71,918																
North/Mid Coast GCG	*15,093*	*26,206*	*1986-95*	*-4.8*	*(4.3)*	*-14.7*	*(3.8)*	*-12.4*	*(5.5)*	*1950-95*	-2.3	*(0.5)*	*1978-95*	*-9.1*	*(1.5)*	*1978-95*	*-9.8*	*(2.0)*
Nehalem			1986-95	-7.7	(7.5)	-17.3	(7.1)	-16.9	(12.2)	1950-95	-2.9	(0.7)	1978-95	-9.6	(2.7)	1979-95	-10.1	(4.9)
Tillamook			1986-95	-9.2	(9.5)	-18.6	(6.4)	-3.3	(10.0)	1950-95	-3.0	(1.0)	1978-95	-15.4	(2.2)	1978-95	-8.9	(3.6)
Nestucca			1986-95	2.8	(6.2)	-7.9	(3.8)	7.6	(8.9)	1950-95	-2.2	(1.6)	1978-95	-10.0	(2.2)	1980-95	-10.4	(4.2)
Siletz			1986-95	-9.3	(7.8)	-18.8	(6.1)	-12.2	(4.4)	1980-95	-5.9	(3.4)	1980-95	-13.4	(3.0)	1983-95	-11.1	(2.7)
Yaquina			1986-95	7.8	(6.6)	-3.4	(4.3)	-9.7	(7.4)	1950-95	-2.3	(1.1)	1978-95	-3.9	(2.7)	1979-95	-11.4	(6.1)
Alsea			1986-95	-13.7	(5.5)	-22.7	(6.0)	-21.9	(6.9)	1950-95	-2.4	(0.7)	1978-95	-10.7	(2.8)	1978-95	-13.2	(3.0)
Siuslaw			1986-95	-8.7	(4.9)	-18.2	(5.3)	-17.0	(6.3)	1950-95	-0.5	(0.7)	1978-95	-6.9	(2.5)	1978-95	-6.6	(2.6)
Umpqua GCG	*5,148*	*11,521*	*1986-95*	*1.4*	*(5.2)*	*-14.9*	*(6.7)*	-20.7	(7.0)	*1950-95*	-2.3	*(0.8)*	*1983-95*	-0.2	(6.5)	*1983-95*	-8.4	*(6.3)*
Lower			1986-95	1.3	(5.5)	-15.0	(6.9)	-20.4	(7.5)	1950-95	-1.7	(8.0)	1983-95	-0.3	(6.6)	1983-95	-8.9	(6.5)
Upper			1986-95	12.7	(11.3)	-5.4	(11.1)	-27.2	(13.2)	1981-95	31.5	(15.0)	1984-95	9.1	(10.4)	1987-95	-27.2	(13.2)
Mid/South Coast	*23,087*	*32,320*	*1986-95*	*8.5*	*(3.4)*	*-5.8*	*(4.6)*	*-5.4*	*(3.6)*	*1950-95*	-2.2	*(0.6)*	*1983-95*	*-4.7*	*(3.4)*	*1983-95*	-5.6	*(3.4)*
Coastal Lakes			1986-95	1.1	(7.0)	-12.2	(5.4)	-1.8	(9.6)	1970-95	-3.5	(1.4)	1983-95	-10.6	(3.5)	1983-95	-4.7	(5.6)
Coos			1986-95	13.6	(7.2)	-1.4	(4.0)	-5.7	(6.2)	1950-95	-1.8	(0.7)	1983-95	1.7	(3.0)	1983-95	2.7	(5.0)
Coquille			1986-95	2.3	(5.0)	-11.1	(6.7)	-8.5	(5.0)	1950-95	-2.5	(0.6)	1983-95	-9.4	(4.6)	1983-95	-11.2	(4.1)
S Oregon/N Califorina Coasts*																		
Rogue	1,420	1,642	1986-95	5.7	(13.6)	-1.5	(13.1)	-6.2	(17.3)	1980-95	2.5	(6.5)	1980-95	-6.4	(5.4)	1982-95	-5.7	(8.7)

* Trend data for coho salmon from this ESU is limited to the Rogue River population.

APPENDIX A
SUMMARY OF NORTHERN CALIFORNIA AND OREGON COAST COHO SALMON HATCHERY STOCKS

This summary is based on information contained in Brown and Moyle (1991), Brown et al. (1994), Bryant (1994), NRC (1995), CDFG (1995), ODFW (1996, 1997), and conversions with, and comments from, Mark Lewis, Rich Berry, and Kathryn Kostow (all ODFW). This information is summarized in Table 1.

Southern Oregon/Northern California coasts ESU

CDFG (1995) and Brown et al. (1994) presented opposing views regarding the heritage of California hatchery stocks. CDFG argued that, although some hatchery stocks, such as Trinity and Iron Gate, used out-of-basin and out-of-state broodstock, the imported broodstock did not substantially contribute to future generations, resulting in stocks that were largely native despite their apparent ancestry. They based this argument, in part, on genetic data contained in the coastwide status review (Weitkamp et al. 1995) that they suggested indicated that California hatchery stocks were not influenced by exotic (e.g., Columbia River) stocks. In contrast, Brown et al. considered California coho salmon stocks to be "of diverse origin," and argued that the lack of genetic differentiation among coho from different California streams observed by Bartley et al. (1992) was largely due to hatchery supplementation. In the NMFS genetic analyses (Weitkamp et al. 1995), California hatchery coho salmon did not cluster with lower Columbia River fish. However, this does not prove that Cascade (Columbia River) fish, released at both Trinity and Iron Gate hatcheries in the late 1960s, did not contribute to the ancestry of these California stocks. Furthermore, our analysis of Bartley et al.'s data showed that California coho contained considerable genetic diversity, although the effect of hatchery operations on the genetic structure is unclear. The widespread use of a few hatchery stocks may have decreased genetic diversity; however, the importation and subsequent outplanting of exotic broodstock may have contributed to an increased level of genetic differentiation.

Mattole River

Since at least 1987, the Mattole River Support Group (MRSG) has been working to enhance coho salmon populations in the Mattole River. They collect wild brood stock from the Mattole River, raise the progeny, then release the fish back into the river. MRSG has released at least 8,600 fry total (1988, '91) and 12,500 smolts total (1987-88, '92) and 3,000 fish of unknown age (released in 1994) between 1987 and 1994. Our records indicate no coho releases in the Mattole until 1982, when some (<3,000) Noyo fish may have been released. Since then, all artificially propagated coho salmon released into the Mattole River have been those by MRSG, described above.

Eel River

Eel River stock is sporadically propagated by three cooperative programs--Salmon Restoration of California, Garberville Rotary Club, and Pacific Coast Federation of Fisherman's Association, from brood stock collected at traps on the S.F. Eel at Redwood Cr. and the Hollow Tree. Cr. Egg Taking Station, and at other locations in the Eel basin. In all cases, coho propagation is not the primary objective of the operations, consequently coho salmon are collected only when returns are large, resulting in the sporadic production. Coho releases by these programs have consisted of Eel [Cedar Cr. or Redwood Cr] stock (4,000 fry in 1996, 50,000 smolts in 1965) and Garberville stock (11,000 fry in 1987).

Other stocks released into the Eel River by other hatcheries include: Alsea (65,000 fry in 1963, 130,000 smolts in 1972); Big Cr. (20,000 smolts in 1968); Klamath (17,000 fry over 3 years, 1983-87); Klaskanine (20,000 fry in 1964; 39,000 smolts over 3 years, 1966-69); Mad (3,000 smolts in 1986); Noyo (37,000 fry over 2 years, 1982, 1995; 316,000 smolts over 4 years, 1970-73); Trinity (5,000 smolts in 1979); and unknown [from Prairie Cr. hatchery] (50,000 fry in 1968, 337,000 smolts in 1964-69).

CDFG (1995) stated that it considered Hollow Tree Cr. (Eel R.) stock to be "similar" to its respective native run.

Mad River

Mad River Hatchery has used the greatest number of coho salmon brood stocks, both out-of-basin and out-of-state, of any CDFG hatchery. The stock was begun with Noyo brood stock released in 1970, and Noyo was released from the hatchery in an additional 12 years: 1971, '72, '75, '76, '81, '85, '88-'91, '93-'94, and '96. Other stocks released from the hatchery include Alsea (1973), Klamath (1981, '83, '86-89), Klaskanine (1973), Prairie Cr. (1988, '90), Sandy (1980), Green River (1979), Trask (1972), Trinity (1971) and unknown (1977).

Darrah Springs also released numerous coho salmon into the Mad R. during the 1960s and 1970s, using various exotic stocks including Big Cr. (1968), Klaskanine (1962-69), unknown (1961), and Noyo (1970).

CDFG (1995) noted that nonnative stocks had been released into the Mad River basin 18 times since 1970, that the hatchery run had never exceeded 2,000 spawners, and that only twice in 18 years had it exceeded 1,000 fish. Brown et al. (1994) referred to the heritage of this stock as "diverse."

Trinity River

The Trinity River Hatchery started releasing coho salmon in 1960 using progeny of fish collected at the weir, but released Eel River (1965), Cascade (1966, '67, '69), Alsea (1970) and Noyo (1970) stocks as well. Since 1970, only Trinity River stock has been released from the hatchery--the progeny of adults collected at the hatchery weir. The same exotic stocks releases from the hatchery were also released elsewhere in the Trinity basin during the same years.

CDFG (1995) acknowledged that Trinity River Hatchery imported eggs from a variety of sources in the early years of operation, including Cascade Hatchery (Columbia River). However, they argued that "recent genetic investigations done by the NMFS [referring to the coastwide status review] show no influence from Cascade stocks from the Columbia River basin" (p. 5). (In our (NMFS) genetic analyses, Trinity Hatchery coho salmon do not cluster with lower Columbia River fish. However, this does not prove that Cascade fish did not contribute to the ancestry of these California stocks.) Brown et al. (1994) considered Trinity Hatchery stock to be basically nonnative because, although it was begun with native fish, releases were quite small until nonnative stocks (Eel, Cascade, Noyo) dominated releases in the late 1960s through 1970. However, Brown et al. (1994) conceded that natural production occurred above the hatchery through the 1960s, and these wild fish may have been used as broodstock and moderated the non-native nature of the stock.

Iron Gate (Klamath)

Iron Gate Hatchery was begun with Cascade (Columbia River) coho released in 1966-68 and 1970. Other stocks released from Iron Gate include Trinity (1969, 1977 and 1994) and unknown (1970-71). With the exception of a release of Trinity Hatchery coho salmon in 1994, only Klamath stocks (Klamath or Iron Gate, all progeny of fish returning to the hatchery rack) have been released at the hatchery since 1977.

The Klamath basin has also been planted by other hatcheries including Darrah Springs and Mad River Hatchery. Stocks released from these two have included Alsea (1962-63, '71-72), Big Cr. (1968), Cascade (1970), Klaskanine (1964, '66-67, '69), Noyo (1970-71), and Freshwater Cr. (1988).

CDFG (1995) acknowledged that Iron Gate Hatchery imported eggs from a variety of sources in the early years of operation, including Cascade Hatchery (Columbia River). However, they argued that "recent genetic investigations done by the NMFS [referring to the coastwide status review] show no influence from Cascade stocks from the Columbia River basin" (p. 5). (NMFS genetic analyses (Weitkamp et al. 1995) indicated that Iron Gate Hatchery coho salmon did not cluster with lower Columbia River fish. However, this does not prove that Cascade fish did not contribute to the ancestry of these California stocks). Brown et al. (1994) considered Iron Gate Hatchery stock to be basically nonnative because it was begun with an exotic (Cascade) stock, and returns from these releases were relatively high and therefore would have contributed to future generations.

Rowdy Cr.

Since 1986, the Rowdy Cr. Hatchery has sporadically been raising and releasing coho salmon in the Smith Basin, all progeny of fish trapped at their weir. Releases occurred in 1986 (21,000 smolts), 1987 (4,000 fry), and 1996 (12,000 smolts). Various stocks were released into the Smith River during the 1960s and early 1970s prior to the construction of the Rowdy Cr. Hatchery. These stocks included Alsea (196-73), Big Cr. (1968), Green R. (1967), Klaskanine (1965-69), Noyo (1965-73), and Quilcene (1962).

Rogue River (stock 52)

This stock is exclusively raised at Cole Rivers Hatchery, which began operation in 1973 to mitigate for lost salmon and steelhead production due to the construction of Lost Creek Dam. The first three brood years (1977-79) were begun with wild fish trapped in the river. The hatchery trap, located immediately below Lost Creek Dam, captures all returning hatchery fish as well as any wild fish which stray into the hatchery. Prior to 1994, returning Cole Rivers hatchery adults were not distinguishable from natural fish, thus hatchery staff may have used both natural and hatchery fish for broodstock. Since 1994, when the first 100% marked brood returned, hatchery staff have observed unmarked fish swimming into the hatchery and have incorporated these fish into the brood stock. Starting with the 1991 brood year, this stock has been 100% marked. Two hundred thousand smolts are released annually. There have been no releases of other stocks into the Rogue River from Cole Rivers Hatchery, although Cole Rivers Hatchery raises other stocks for release in their respective basins.

ODFW (1997) considered this stock to be part of the Southern Oregon/Northern California Coasts ESU because it was recently derived from natural Rogue River fish, and a few (<2%) wild fish were annually incorporated into the hatchery broodstock. However, they did not feel that it was essential for recovery because the natural population was in "good" condition.

Oregon Coast ESU

Coos River (Stock 37)

This stock forms the basis for two stocks--a rehabilitation stock that is 100% wild fish, and a fishery augmentation stock that incorporates about 30% wild fish. This stock was begun with the 1983 brood utilizing wild Coos River fish. This program currently uses fish collected and spawned at STEP traps operated on Noble Cr. (hatchery production area), and on Priorly Cr. and the South and West Forks of the Coos (wild trap sites) and then transferred to Bandon Hatchery as green eggs. Fish from the hatchery trap sites are mixed with wild fish at a 7:3 ratio, transported to Cole Rivers Hatchery for raising, marked 100%, and released as smolts in the hatchery production area (Isthmus Slough). Eggs of wild fish are transferred to the STEP Coos Bay hatchboxes for release as unfed fry. Unfed fry are released into streams that have barriers to adult migration (e.g., culverts, impassable falls) or that have been documented to have lower-than-average fry densities that year, given the available habitats. Eggs are transferred to Cole Rivers Hatchery because of low summer water flow levels at Bandon Hatchery.

ODFW (1997) considered this stock to be part of the Oregon Coast ESU because it was derived from natural and hatchery Coos River stock and wild fish were annually incorporated into the hatchery broodstock. However, they did not feel that it was essential for recovery because the natural population was in "good" condition.

Coquille River (Stock 44)

This stock was begun in 1980 with wild Coquille River coho. It currently uses fish returning to the Bandon Hatchery and fish collected from various sites within the Coquille Basin (a mixture of approximately 75% hatchery and 25% wild fish). About 60,000 eyed eggs are transferred to Butte Falls Hatchery for rearing to smolts and returned to Bandon Hatchery (Ferry Cr.) and Meadow Hill (Sevenmile Cr.) for acclimation and release in the lower Coquille River. These fish are 100% marked prior to release. About 275,000 fish are released as fry in the Coquille Basin by both STEP Coquille and the Bandon Hatchery. About 20,000 coho salmon are released as unfed fry in New River by STEP South Coast. The transfer to Butte Falls is necessary because of low summer water flows at Bandon Hatchery. Unfed fry are planted into streams that have been documented to have lower-than-average fry densities that year, given the available habitats.

Prior to the start of this stock, Bandon Hatchery had been producing coho salmon since at least 1950, although no records of coho releases between 1966 and 1982 are available. All available records indicate only Coquille stock was released into the Coquille river from Bandon hatchery, although the hatchery has raised several other stocks for release into other basins.

ODFW (1997) considered this stock to be part of its ESU because it was derived from natural and hatchery Coquille River stock and wild fish were annually incorporated into the hatchery broodstock. However, they did not feel that it was essential for recovery because the natural population was in "good" condition.

Cow Cr. (Stock 18)

Cow Cr. stock was begun with the 1986 brood with wild South Umpqua coho. Since its inception, the broodstock has been incorporating about 50% wild fish. The hatchery fish are now 100% marked. This stock uses fish collected in the South Umpqua at Happy Valley and Galesville Traps, and other locations where fish are accessible (Cow Cr., S. Umpqua). About one-half of the eyed eggs are transferred to Butte Falls Hatchery for rearing and released as smolts (125,000) in the South Umpqua. The remaining eggs are released as fry in the South Umpqua by STEP volunteers into streams which have lower than average smolt densities in that year. Cow Cr. fish are transferred to Butte Falls Hatchery (Rogue R. Basin) for rearing because the local hatchery, Rock Cr. Hatchery on the North Umpqua, has insufficient space and water flow to rear them.

ODFW (1997) considered this stock to be part of the Oregon Coast ESU because it was derived from natural and hatchery Cow Creek stock and wild fish were annually incorporated into the hatchery broodstock. However, they did not feel that it was essential for recovery because the natural population was in "fair" condition.

North Umpqua (Stock 55)

This stock is raised exclusively at Rock Cr. Hatchery (North Umpqua) using fish collected at the Winchester Dam Fish Ladder (North Umpqua) and returns to the Rock Cr. Hatchery. This stock is a mix incorporating about 80% hatchery fish and 20% wild fish. This mixture can be maintained because North Umpqua stock have been 100% marked (Ad + CWT or ventral fin clip) since at least the 1983 brood year. This stock is released through both the STEP Umpqua as unfed fry, and at the hatchery as smolts (140,000/yr.). It is not clear whether this stock incorporated broodstock from the original Rock Cr. Hatchery stock, which it replaced. Rock Cr. Hatchery began operation in 1921 and records are available for releases in 1957-58, 1965, and 1973-95. During those years, only Umpqua and Cow Cr. fish were released into the Umpqua system, with the exception of 27,000 Nestucca smolts released in 1958. However, the stocks released between 1965 and 1977 are unknown, and may have included out-of-basin stocks.

ODFW (1997) considered this stock to be part of the its respective ESU because it was derived from natural and hatchery N. Umpqua River stock and wild fish were annually incorporated into the hatchery broodstock. However, they did not feel that it was essential for recovery because the natural population was in "fair" condition.

Tahkenitch/Siltcoos (Stock 105)

This stock has been raised at Fall Cr. Hatchery using wild fish collected every year from the Tahkenitch Basin, starting with brood year 1990. This stock has been used to plant various lakes and creeks in the Siuslaw Basin and Tahkenitch Lake (2,000 smolts/year, in 1991, 1992 brood years). This stock may be discontinued after 1997 release year (1995 brood year).

ODFW (1997) considered this stock to be part of the Oregon Coast ESU because it was annually derived from natural Tahkenitch/Siltcoos wild stock. However, ODFW did not feel that it was essential for recovery under present conditions.

Alsea River and tributaries (Stock 43)

This stock was begun in 1989 with wild fish trapped at several locations in the Alsea basin for 3 consecutive years. In only two years were enough fish trapped to collect eggs (1989 brood produced 57,000 smolts and 1991 brood produced 8,000 smolts), and since the initial release, only the 1989 brood line has been continued. All fish are released at Fall Cr. Hatchery. The 1992 brood year was composed of both returning fish from the 1989 brood (about 45%) and trapping of additional wild fish (55%). The 1995 brood is composed entirely of returning 1992 brood releases. Alsea River stock reared prior to the 1989 brood was not maintained as a separate stock. The current Alsea River stock is 100% marked to distinguish returning adults from Fall Cr. stock at the Fall Cr. Hatchery. The Alsea R. stock also has a later run timing than Fall Cr. stock, and in 1992 and 1995 run years shows nearly complete temporal separation from Fall Cr. stock. See Fall Cr. stock for further discussion about the Fall Cr. Hatchery.

ODFW (1997) considered this stock to be part of the ESU because it was derived from natural and hatchery Alsea River stock, and wild fish were annually incorporated into the hatchery broodstock. They considered this stock to be essential for recovery, but only if the present natural population declined.

Fall Creek (Stock 31)

This stock is also raised at Fall Cr. Hatchery using fish collected at the hatchery weir. Since 1958, this stock has relied on fish swimming into Fall Cr. Hatchery for its brood stock. Prior to 1958, brood stock was collected from various trapping sites in the Alsea Basin. At Fall Cr. Hatchery, this stock is distinguished from the Alsea R. stock by differential marking and slightly earlier run timing (see Alsea stock discussion, above). In addition to releases of Fall Cr. and Alsea R. stocks at the Fall Cr. Hatchery, Nehalem (1960), Coos (1960, 1963-64), Klaskanine (1949-50, 56), Big Cr. (1953-55) and Trask (1961-62) stocks have also been released into Fall Cr. Since 1989, Fall Cr. Hatchery has also raised Siletz (1989 brood), Coos (1990 brood), and Tahkenitch/Siltcoos (1990-1995 broods) stocks for release back into their respective basins.

ODFW (1997) considered this stock to be part of the Oregon Coast ESU because it was derived from natural Alsea River stock, although few wild fish had been incorporated into the broodstock in recent years. There has been substantial natural production in the creek above the hatchery that was thought to have been incidentally incorporated into the broodstock, and therefore kept the hatchery stock from substantially diverging from wild fish in the basin. ODFW did not consider this stock suitable stock for recovery as long as Alsea River stock (43) was available.

Salmon River (Stock 36)

This stock is raised at Salmon River Hatchery using progeny of fish collected at the hatchery weir. The stock was begun in 1976 when the Salmon R. Hatchery became operational, using wild Salmon River fish. The hatchery is located at the head of tidal influence and has an electric barrier spanning Salmon River at that point. This allows for collection of returning hatchery fish as well as wild fish headed up river, which may be incorporated into the broodstock (these wild fish have been identified by scale analysis). All smolts released are now 100% marked. Although other stocks (Siletz, Fall Cr.) have been raised by the hatchery, only Salmon R. stock has been released at the hatchery.

ODFW (1997) did not consider this stock to be part of the Oregon Coast ESU because it was derived from natural and hatchery Salmon River stocks, and only a few wild fish may have been annually incorporated into the hatchery broodstock. In addition, there were few natural fish that spawned in the river above the hatchery; consequently, there was little opportunity for accidentally introducing wild fish into the broodstock, and the stock may have diverged from wild fish. Finally, stray Oregon Aquafoods (OAF) coho salmon were thought to have had substantial influence on natural spawners in the basin (these fish were derived from Puget Sound stocks), especially because the natural population in the basin had always been small, and therefore more likely to be affected by large numbers of stray fish. ODFW did not consider this stock essential for recovery, but would consider using it for restoration under extreme circumstances. ODFW considered it preferable to use the existing hatchery stock for recovery, even if it had diverged from wild fish, than to bring in stocks from outside the basin.

Siletz River (Stock 33)

This stock was originally begun in 1937 at the Siletz Hatchery with broodstock collected from Rock Cr., which consisted of 1/3 Rock Cr. stock and 2/3 Tenmile Lake stock that year. This stock was moved to the Salmon River Hatchery with the 1986 brood year because of the closure of the Siletz Hatchery. These fish are released into the Siletz River at the old hatchery site or into Yaquina Bay after acclimation at the old OAF site, and brood stock is collected from returning adults at the Siletz Hatchery. All smolts are now 100% marked.

While the Siletz Hatchery was still in operation, stocks released at the hatchery in addition to Siletz included Klaskanine (1949 brood year, less than 200,000 fish released), Trask (733,000 smolts total over 2 years, 1976, 1978), Fall Cr. (101,00 smolts in 1980), and a Nehalem-Siletz mixture (379,000 smolts total over 2 years, 1955, 1960). Since production was moved to the Salmon River, Salmon River stock was released in the Siletz River in 4 years (1981-88), using a total of 510,000 smolts, while approximately 100,000 Alsea and Fall Cr. smolts were released annually in the basin in 1983-86, all 100% marked. Wild brood stock has not deliberately been incorporated into this stock in recent years.

ODFW (1997) did not consider this stock to be part of the Oregon Coast ESU because it was derived from natural and hatchery Siletz River stocks, and few wild fish had been incorporated into the hatchery broodstock. In addition, there was little natural production, both historically and currently, in the stream above the hatchery; consequently, there had been little opportunity for accidentally introducing wild fish into the broodstock, and the stock may have diverged from wild fish. ODFW did not consider it essential for recovery, but would consider using the stock for restoration under extreme circumstances. ODFW considered it better to use the existing hatchery stock for recovery, even if it had diverged from wild fish, than to bring in stocks from outside the basin.

Trask River (Stock 34)

This stock is raised at Trask River Hatchery using progeny of fish that, since 1961, have been collected at either of the hatchery's two traps. One of these traps is located on Gold Cr., adjacent to the upper hatchery ponds, while the other is a pond and fishway located near the lower hatchery ponds, adjacent to Trask River. Neither trap blocks upstream passage to the Trask River. Prior to 1961, brood stock was collected by trapping in Gold Cr. (the current hatchery site), at Beaver Cr. (Nestucca R) from 1927-34, and seining in the Trask River below the hatchery. During 1928-33, two other coastal stocks were released into the Trask River from the Trask hatchery and an unknown stock was released in 1950. Otherwise, only Trask stock fish have been released at the hatchery. Wild brood stock has not deliberately been incorporated into this stock in recent years. All smolts released (200,000/yr in 1996) are now 100% marked.

ODFW (1997) did not consider this stock to be part of the Oregon Coast ESU because it was derived from natural and hatchery Trask River stocks, and few wild fish had been incorporated into the hatchery broodstock. Because there was little natural production both historically and currently above the hatchery, it was believed that there had been little opportunity for accidentally introducing wild fish into the broodstock, and the stock may have diverged from wild fish. ODFW did not consider this stock essential for recovery, but would consider using it for restoration under extreme circumstances. ODFW considered it preferable to use the existing hatchery stock for recovery, even if it had diverged from wild fish, than to bring in stocks from outside the basin.

N.F. Nehalem (Stock 32)

This stock is raised at Nehalem River Hatchery. This stock was begun in 1966 when the Nehalem Hatchery was moved from Foley Cr. (Nehalem River), where it operated from 1926 to 1956, to its current location on the N.F. Nehalem. This stock was begun with a mixture of Foley Cr. Hatchery fish released at the site of the soon-to-be hatchery (1964 and 1965 broods), and wild fish collected from the N.F. Nehalem.

Since 1987, either N.F. Nehalem stock or Fishhawk Cr. stock is released from the Nehalem Hatchery each year; but not both. Fishhawk Cr. stock is released in one cycle (e.g., 1996 brood year) while N.F. Nehalem stock is released in the other two cycles (1994 and 1995 brood years). From brood years 1978 to 1986, both stocks were released in the same years. At that time, Fishhawk stock was 100% marked (ventral fin clips) to differentiate the two stocks when returning as adults. Fishhawk stock may also have a later run timing. All smolts released are now 100% marked.

Other stocks released at the hatchery at its present location include Trask (578,000 smolts total, 1966-67) and unknown (7,824,000 fry and smolts total over 8 years, 1969-77). While still located on Foley Cr., the Nehalem Hatchery released Trask (1929-31, 1933, 1936, 1944, 1947), Necanicum (1934-35), Nestucca (1938), Siletz (1940), Coos (1940), and Klaskanine (1945-46, 1949-50, 1953) fry. Wild brood stock has not been deliberately incorporated into this stock in recent years.

ODFW (1997) considered this stock to be part of the Oregon Coast ESU because it was derived from natural and hatchery Nehalem River stocks, and a few wild fish may have been annually incorporated into the hatchery broodstock. There was also substantial natural production in the creek above the hatchery that was believed to have been incidentally incorporated into the broodstock, and therefore kept the stock from substantially diverging from wild fish in the basin. In addition, N.F. Nehalem stock was started, in large part, with native fish in the 1960s. ODFW felt that it was not an appropriate stock to use for recovery of wild stocks because of its early run timing.

Fishhawk Creek (Stock 99)

This stock is raised at Nehalem River Hatchery using exclusively wild fish collected from Fishhawk Cr. (Nehalem River) during 1978-80 brood years. For the 1981-84 brood years, the broodstock was a mixture of returns from the 1978-80 releases and wild fish collected from Fishhawk Cr. Beginning with the 1985 brood year, the hatchery has relied on returns to the Nehalem hatchery for broodstock for this stock. All smolts released are currently 100% marked. See N.F. Nehalem stock for further discussion.

ODFW (1997) considered this stock to be part of the Oregon Coast ESU because it was recently derived from natural Fishhawk Lake stock, and some wild fish had been incorporated into the broodstock since the beginning of the program. They felt that was essential for recovery, but only if the present population declined.

REFERENCES

Bartley, D. M., B. Bentley, P. G. Olin, and G. A. E. Gall. 1992. Population structure of coho salmon (*Oncorhynchus kisutch*) in California. Calif. Fish Game 78(3):88-104.

Brown, L. R., P. B. Moyle, and R. M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. N. Am. J. Fish. Manage. 14:237-261.

Bryant, G. J. 1994. Status review of coho salmon in Scott Creek and Waddell Creek, Santa Cruz County, California. Natl. Mar. Fish. Serv., SW Region, Protected Species Management Division, 102 p.

CDFG. 1995. Letter by C.F. Raysbrook to G. Griffin dated Oct. 23, 1995. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Natural Resources Consultants, Inc (NRC). 1995. Database of artificially propagated anadromous salmon (database). Prepared for NMFS Conservation Biology Program, Coastal Zone and Estuarine Studies Division, Northwest Fisheries Science Center, Contract No. 50ABNF400128.

ODFW 1996. Fish Propagation Program, Oregon Department of Fish and Wildlife. Materials provided by R. Berry to S. Smith and L. Weitkamp, 16 August 1996. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

ODFW 1997. Letter from R. Berry to M. Schiewe regarding Oregon coho salmon hatchery stocks. Dated 24 February 1997, 2 p. + attachments. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Weitkamp, L. A., T. C. Wainwright, G. J. Bryant, G. B. Milner, D. J. Teel, R. G. Kope, and R. S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. NOAA Tech. Memo. NMFS-NWFSC-24. 258 p.

Table 1. Summaries of coho salmon hatchery stocks in ESUs proposed for listing

Stock name (Stock No.)	First year of propagation	Heritage	Natural fish regularly incorporated?
S. Oregon/N. California Coasts ESU			
Mattole R.	1987	native	yes[a]
Eel R.	1965[b]	native	yes[a]
Freshwater Cr.	late 1960s	exotic	incidental
Mad R. Hatchery	1970	exotic	no
Prairie Cr.	1950s? [c]	exotic?	?
Trinity R. Hatchery	1960	native/exotic?	no
Iron Gate (Klamath)	1966	exotic	no
Rowdy Cr.	1986	native	yes[a]
Rogue R. (52)	1977	native	incidental
Oregon Coast ESU			
Coos R. (37)	1983	native	30-100%/yr
Coquille R. (44)	1980	native	25% per yr
Cow Cr. (18)	1986	native	50% per yr
N. Umpqua R. (55)	1921?	native	20% per yr
Tahkenitch/Siltcoos (105)	1990	native	Yes
Alsea R. & tribs (43)	1989	native	1989-92
Fall Cr. (31)	1958	native/exotic	No
Salmon R. (36)	1976	native	Incidental
Siletz R. (33)	1937	native/exotic	No
Trask R. (34)	1920s?	largely native	No
N.F. Nehalem (32)	1966	largely native	No
Fishhawk Cr. (99)	1978	native	No

[a] Stock reared sporadically, therefore assuming fish collected at rack are largely natural.
[b] Sporadic since then.
[c] Our records for this facility begin in 1962.

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April 2, 1997

MEMORANDUM FOR: F/NWC1 - Michael H. Schiewe

FROM: F/NWC1 - Thomas C. Wainwright *TC Wainwright*

SUBJECT: ODFW coho sustainability model

The following is my assessment of the "habitat-based life cycle model" of Oregon coastal coho salmon, developed by Tom Nickelson and Pete Lawson of the Oregon Department of Fish and Wildlife (ODFW). These comments are based on a draft manuscript by Nickelson and Lawson ("Population dynamics of Oregon coastal coho salmon: application of a habitat-based life cycle model" dated February 21, 1997). This assessment incorporate concerns raised by Robin Waples; additional comments from Mike Murphy (NMFS Auke Bay Laboratory) are attached.

Model Synopsis

The model consists of two somewhat independent parts: A habitat (or "production") component and a population dynamics ("forward simulation") component. The first part uses freshwater habitat survey information to predict smolt capacity and average production as a function of spawner density for specific stream reaches within basins. The second part combines the habitat-based production function with interannual variation in freshwater and ocean survival, harvest rate information, and some small-population genetic and demographic risk factors to predict statistical distributions of future population abundance, from which some measures of risk can be derived.

The habitat component predicts smolt capacity and production for individual reaches within basins. It is based largely on the overwinter survival portion of ODFW's Habitat Limiting Factors Model (HLFM), an earlier version of which was published in 1992. Where winter survey data is available, HLFM was used directly to predict smolt potential. However, because ODFW has much more extensive data from summer habitat surveys than from winter surveys, over-winter smolt potential is estimated for most reaches via a regression relating predictions of winter smolt potential from HLFM to summer habitat characteristics (channel width, gradient, number of beaver dams, and percent pool area).

The regression is based on 74 stream reaches where both summer and winter habitat surveys have been conducted. This provides an estimate of smolt potential for every reach on the coast with either winter or summer habitat survey data. Next, the model predicts average over-winter survival for each reach, based on a log-linear regression of estimated survival (from studies on 5 streams over a number of years) on predicted smolt potential. Finally, egg deposition needed for full seeding is estimated by dividing predicted smolt potential by the product of average over-winter survival and average egg-to-summer-parr survival (assumed to be 7%). Key assumptions in the habitat component include: 1) over-winter habitat is the primary bottleneck to freshwater production, 2) survival from egg to summer parr is 7% for all reaches at full seeding, and 3) empirical smolt potential and survival relationships derived from data for a subset of streams apply uniformly to all streams on the Oregon coast.

(Note that in this model, smolt capacity is not extrapolated per se to entire basins, nor is the number of spawners needed for full seeding estimated directly. Nickelson has used other methods to derive spawners needed to achieve full seeding for each coastal basin under different ocean survival conditions in a separate document, which I have not reviewed.)

The dynamic component is a Monte Carlo simulation, making multiple runs of the model and randomly drawing values for variables in each run, thus producing a statistical distribution of outcomes. (Present model applications have used 1,000 replicate runs, each either 10 or 33 generations in length.) It begins with three parameters for each reach as estimated by the habitat component: maximum smolt capacity, average overwinter survival rate, and egg deposition needed to produce maximum smolts. These estimates are used directly for reaches with habitat survey data; for unsurveyed reaches, the model extrapolates by randomly assigning parameters from surveyed reaches within the same basin. This technique assumes that surveyed reaches are a representative sample of all coho salmon habitat in the basin. Surveyed reaches account for between 16% and 64% of available coho salmon habitat in various basins, and the remainder are extrapolated.

Once the initial parameters are assigned for each reach, an initial population of spawners is assigned to each reach. The current application bases initial abundance on the 1995 stratified-random survey population estimates. This initial cohort in a single reach is then simulated through a number (currently 10 or 33) generations, with eggs, summer parr, smolts, and adults estimated sequentially in each generation. To generate eggs, the total spawning run is divided randomly into two time periods (early and late spawners), and then spawners in each time period are divided randomly into males and females. Egg deposition for each time period is then estimated as 2500 times the number of females present, or zero if no males are present. The number of summer parr is then calculated from a random, density dependent egg-to-parr survival function (estimated from a study conducted in the Alsea watershed in the 1960s and early 1970s), truncated above to avoid unrealistic survivals. At this point, an adjustment is made to reduce survival by a cumulative genetic fitness factor. The change in this fitness factor each generation is based on a theoretical relationship between effective population size and rates of accumulation of deleterious mutations. The number of smolts is calculated by multiplying summer parr by a randomly-selected over-winter survival rate with mean survival estimated as in the habitat component. This survival rate is truncated both above and below to avoid unrealistic values. Number of smolts produced is capped by the smolt capacity estimated in the habitat component. Adults (pre-harvest) are produced by multiplying smolts by a random marine survival rate, with the mean rate indexed to twice the marine survival estimated for hatchery stocks. Variation in marine survival is treated in two separate ways: for 10-generation simulations, average survival is held constant at pre-selected values ranging from 1.5% to 5%; for 33-generation simulations, average survival is varied according to an index based on the pattern of historical change in the Aleutian Low Pressure Index (ALPI). Spawners are then calculated as adults multiplied by 1 minus harvest rate, where harvest rate is a specified constant for each run. On arrival back to the basin, straying is simulated by randomly reassigning 5% of returning adults to a different reach within the basin. There is no straying among basins in the model.

Some assumptions of the dynamic component are: 1) age-2 males (jacks) do not contribute to spawning, 2) strays redistribute uniformly across the basin, 3) parr-survival measurements from the 1960s and 1970s in the Alsea basin are applicable in other basins at the present time, 4) errors estimated in survival regressions adequately reflect true patterns of natural variation, 5) reaches included in habitat surveys are representative of conditions throughout the basin, 6) a single male can effectively fertilize eggs from any number of females, 7) wild fish have twice the ocean survival of hatchery fish, 8) variation in egg-to-parr, parr-to-smolt, and marine survival rates are independent of each other, and 9) (for the 33-generation simulations) historical patterns of variation in ALPI accurately reflect future variation in marine survival of coho salmon.

Results of the model are summarized in several forms: as a prediction of the distribution of good quality habitat among basins (Nickelson and Lawson Fig. 8), and as predictions of three components of future population status (Nickelson and Lawson Fig. 11-15): median ending population, probability of population decline, and probability of quasi-extinction (population dropping below 50 spawners in a given basin). The estimates of extinction probabilities do not include all factors necessary for a proper extinction risk estimate, and the authors caution that "our results in this area must be viewed as exploratory" (Nickelson and Lawson, 1997, p. 2).

General Evaluation

This model represents a substantial effort to incorporate in a single model a variety of factors affecting coho salmon populations, including freshwater habitat heterogeneity, small population demography, small-population genetics, harvest, and climate variation. It is by far the most complete attempt to address in a single analysis the complexities of salmon metapopulation dynamics and risks to sustainability, and the only existing salmon dynamics model to directly use empirical data on freshwater habitat quality over a broad regional scale (although a similar habitat-based model is being developed by Ray Hilborn's students at University of Washington). Where assumptions had to be made, the authors were conservative (i.e. erring on the side of overestimating risk) in most cases. However, the model suffers from several shortcomings, in part reflecting lack of information on important processes, but more largely as a result of the extremely short time frame in which the model was constructed. Some important factors (such as the genetic and ecological effects of hatchery production) are not included, and the inclusion of others (such as small population demography and genetics) is incomplete. To date, there has been little effort to validate the model or its components, and in particular there has been no attempt to compare results of the dynamic component with historical abundance data to check for biases in trend or variability, both of which are vital concerns if the model is to be used for assessing sustainability or extinction risk. The model is very complicated, and thus very difficult to fully test and evaluate in a short time frame.

Limitations

As with most ecological models, the current version of this model is only one iteration of a work in progress. As such, there are a number of areas where improvements could be made, including biological factors not (or not fully) included in the model, uncertainties regarding model structure, and describing and validating model results. Some of the factors not fully included in the model are: effects of hatchery production (e.g. genetic effects, disease transmission, competition), climate effects on freshwater production (e.g. effects of variation in streamflow and temperature), variation in predation rates (especially by birds, introduced fish species, or marine mammals), and anthropogenic effects on water quantity and quality.

Two issues regarding model structure could have significant effects on model results: dynamics of populations at very low abundance, and the incorporation of environmental variation. When populations decline in abundance, two effects can change the intrinsic growth rate. First, compensation (increase in population growth rate with declining abundance) may occur as a result of reduced intra-species competition. Second, depensation (decrease in growth rate with declining abundance) may occur for a variety of reasons, including ability of adults to find mates, randomness in sex ratios, and increases in relative predation rates. In general, compensatory effects will dominate at moderate abundances, while depensatory effects become strong only at very low abundance. The balance between these two effects is a critical determinant of dynamics of small populations, and especially of extinction risk. Based on empirical data, the model has high compensation in survival from egg to parr. Without strong depensatory effects to balance this, the model will predict that populations are very resilient and resistant to extinction. Unfortunately (at least for resolving these issues) there is little empirical information for salmon populations at very low abundance, and the authors have been forced to make some mechanistic assumptions about depensatory effects. They have included what they believe to be reasonable mechanisms affecting spawning at low densities, and have included small-population genetic effects that (when accumulated over several generations) reduce fitness and survival. However, these assumptions need to be regarded as only one of several possible choices for small-population behavior, and other scientists facing the same problem might have modeled depensation differently. Similarly, there is little information on which to base long-term predictions of the effects of environmental variation on populations. Again, the author's have chosen a structure for environmental variation that they believe is reasonable, but other scientists might reasonably have assumed other structures. While these choices may not have a large effect on the average population trend, they almost certainly have a large effect on estimates of extinction risk.

Two issues relate to the degree of confidence in model predictions: validation and the treatment of uncertainty. Validation is the process through which modelers demonstrate that a model provides a sufficiently accurate depiction of reality, where the meaning of "sufficiently accurate" depends on the requirements of the application. Models are essentially a form of scientific hypothesis, and while it is easy to invalidate a model (by demonstrating that it does not match with observations of reality) there is no such thing as complete validation (proof of correctness). General stages of ecological model validation are 1) confirmation that the model can reproduce the data on which it is based, 2) confirmation that the model can predict similar data for another time period or location, and 3) confirmation that the model can effectively predict behavior outside the range of information used to construct it. Confidence in model predictions increases through the three stages. To date, validation of the coho model has been limited to comparing model prediction of initial spawner distributions across habitat with distributions observed in spawner surveys, comparing predicted smolt production with general ranges observed in various field studies, and comparing predictions of mid-1990s spawning abundance for three basins (starting the model with late 1970s abundances) with spawning survey estimates of abundance. Stronger validation might include retrospective comparisons of predicted and observed trends and variability in spawning, and stream-by-stream comparisons of predicted and observed smolt production. However, both of these may be difficult with the current model formulation and existing data.

Treatment of uncertainty is always a difficult problem. Risk assessment requires considering three types of uncertainty: incomplete knowledge (uncertainty in model structure and parameter estimates), process variation (environmental and demographic randomness), and possible errors in conducting assessments (e.g. Suter and Barnthouse 1993). The coho model includes process variation, but does not deal with the other sources of uncertainty. Two issues in model structure were discussed above. Parameter estimation uncertainty refers to the uncertainty we have in estimating fundamental variables in the model, for example the parameters of survival regression equations or the multiplier used to convert hatchery-based ocean survival estimates to wild fish survival rates. For simple models, such uncertainty can be formally incorporated into the model through the use of Bayesian statistics, but that is seldom feasible for models with many parameters or tedious computations. Formally incorporating either structural or parameter variation in the coho model is probably beyond available computational capacity, so these uncertainties will have to be evaluated through limited sensitivity analyses and scientific judgement.

The authors have plans to address some of these areas in the future, but others may be too difficult to address in a quantitative manner, and will remain as uncertainties that need to be addressed in interpreting predictions from the model.

Utility for Specific Applications

Despite the shortcomings outlined above, the model is useful for a number of purposes. First, it is the first working model for salmon I am aware of that relates habitat heterogeneity to population dynamics. This is a topic we have considered in past risk evaluations, but have never had any ability to consider quantitatively. Early model results have provided some interesting hypotheses about the relationship between freshwater habitat occupancy and ocean productivity. The model thus has potential as a tool to guide our judgement about issues of habitat occupancy and population resilience in making risk evaluations. Second, the habitat component provides at least rough estimates of current habitat capacity and smolt potential. These estimates need to be interpreted in light of the assumptions that are made in the model, and it would be nice to have some confidence intervals on the estimates, but the model probably provides estimates that are better than what we previously had. Third, while the model may not yet be sufficiently developed to be used for formal extinction risk assessment or sustainability analysis, the population dynamics component can provide some relative comparison of effects of alternative management schemes and can be useful in identifying areas of uncertainty (such as dynamics at very low abundance) that need further research. It can also contribute to assessing extinction risk or sustainability, so long as cautious judgement is used regarding model limitations and remaining uncertainties.

Peer Review Comments

ODFW submitted a very early draft of the model documentation to an American Fisheries Society panel for peer review. All three reviewers have experience with risk assessments, and all have some (but not extensive) experience with salmon. Two reviewers come from fisheries harvest management backgrounds, and the other is a population ecologist with substantial background in extinction risk theory. None (as far as I know) have extensive knowledge of habitat issues.

The draft that was submitted for review was very sketchy, and described an early version of the model, which has since been extensively revised. For this reason, specific issues in the peer review comments are not necessarily still relevant, but some major issues are. In general assessments of the model, two reviewers felt the habitat component was a reasonable approach to modeling habitat. One felt that the general structure of the dynamic component was a reasonable approach for population viability analysis, while another described the model as "seriously deficient" for estimating extinction risk. Major concerns raised were the lack of regression statistics for the various submodels, failure to address many influential factors, insufficient data to validate the model, failure to incorporate full small-population stochasticity, inconsistent and poorly justified methods for environmental variability, use of a single set of production parameters across all basins, and concern over accuracy of harvest rate estimates used.

Relation to Other Analyses

This model is one of three analyses of population status considered by the OCSRI science team. The others were a statistical trend analysis by Carl Schreck (OSU) and a simple statistical extinction risk model developed by Mark Chilcote (ODFW). Both of these approaches suggested a higher degree of risk facing coastal coho salmon populations than the Nickelson-Lawson model. Neither has been revised since the August draft of the OCSRI plan, and neither was submitted for formal peer review. The main apparent reason that the Chilcote model predicts a higher extinction risk is that it incorporates a much higher level of depensation at low spawner abundance. Given our high degree of uncertainty regarding dynamics of small salmon populations, all three approaches should be given some weight in evaluating risk.

Uncertainties and Areas for Improvement

As described under "Limitations" above, the model does not incorporate certain important factors, and other factors required assumptions or parameter estimates with limited supporting information. The following paragraphs discuss a few such issues not discussed elsewhere.

Straying--The model assumes a constant 5% rate of straying of adults from their natal habitat, with these individuals being uniformly redistributed among all habitat areas in the basin. There is little information on which to base the estimate of straying rate, but there appears to be some evidence that strays more frequently reach areas near their natal habitat rather than other parts of basins, and that straying rates may change with population density. Both issues could strongly affect model predictions, especially of extinction risk. Straying is the only way that coho can recolonize empty habitat, and the interactions between straying and changes in productivity of habitat patches over time determines the proportion of habitat occupied and the overall productivity of the basin population, thus strongly affecting the overall population dynamics.

Changes in fitness--The model incorporates long-term reductions in fitness due to accumulations of deleterious mutations, but it does not appear that this treatment adequately reflects Michael Lynch's results that are cited in the paper. The model ignores other factors that can more strongly affect average fitness of populations, such as artificial selection by fishing and interbreeding with hatchery fish (see below).

Effects of hatchery production--The presence of large numbers of hatchery fish in natural environments can have substantial effects on the genetics and demographics of natural populations, and these effects were of high concern to the NMFS Biological Review Team for several populations of coho salmon in Oregon. Genetic effects result from interbreeding of natural and hatchery fish in either natural habitat or in hatcheries, and such interbreeding can affect the average fitness of natural populations as well as reducing diversity between populations. Also, hatchery fish may compete with natural fish during most life-history stages, thus reducing productivity of natural populations. Ignoring these effects necessarily results in an overestimate of productivity of natural populations, although the magnitude of this problem is difficult to determine.

Parameter estimation--The methods used to estimate survival and process variation parameters are not statistically rigorous. Of particular concern is the use of standard predictive regression when there is clearly substantial measurement error in both the X and Y variables in the regression model. This introduces the potential for serious biases in two critical equations in the model: the prediction of overwinter survival as a function of estimated potential smolt density (Nickelson and Lawson 1997, eq. 2 and Fig. 2) and the prediction of egg-to-parr survival from estimated relative seeding level (eq. 5 and Fig. 4). The latter relationship is particularly troublesome because parr density is apparently on both sides of the equations (i.e. as the X variable and as a divisor of egg density in the Y variable); depending on the magnitude of estimation error, this could lead to a substantial overestimate of the exponent in eq. 5. This exponent is the critical parameter that determines the degree of resiliency of populations in the model. A related concern is the lack of accounting for error in habitat capacity estimates generated by the HLFM model. For this application, the amount and quality of available habitat is estimated from samples covering 16-67% of individual basins and the model uses randomization to simulate error in applying these estimates to non-sampled areas, but there is no inclusion of error associated with the original estimates. By failing to include this error in a quantity that is the basis for further estimates in the model, the overall degree of confidence in model results is overstated.

Further information is needed on sampling design and confidence intervals to evaluate this source of error.

Summary

The coho salmon sustainability model developed by Nickelson and Lawson of ODFW represents a substantial effort to incorporate a variety of factors affecting populations in a single analysis. It suffers from some shortcomings as a result of incomplete information and a very short time frame for development, and the authors intend to address many of these shortcomings in future versions of the model. Limitations to using the model relate to several potentially important factors not (or not fully) included in the model, specific choices of model structure in face of uncertain information, and lack of full validation and analysis of uncertainty. Still, the model provides useful predictions for some purposes (habitat heterogeneity, habitat capacity, and comparative population dynamics), although it is not sufficiently developed to be used as a complete analysis of extinction risk or population sustainability. This model is only one of three analytic approaches considered by the OCSRI Science Team, and its predictions should be interpreted along with those of the other two approaches.

References

Nickelson, T. E., and P. W. Lawson. 1997. Population dynamics of Oregon coastal coho salmon: Application of a habitat-based life cycle model. Draft, 21 February 1997. (Attachment A to Section 13, Chapter 4 of OCSRI Draft Conservation Plan dated 24 February 1997.) 35 p.

Suter, G.W., II, and L. Barnthouse. 1993. Assessment concepts. Ch. 2 in G.W. Suter II (ed.), Ecological Risk Assessment. Lewis Publishers, Boca Raton. p. 21-47.

ATTACHMENT

Model Review by Mike Murphy, NMFS Auke Bay Laboratory

The ODFW coho production model has great heuristic value for studying large-scale interactions between habitat factors and coho salmon population dynamics. As with any model, however, it incorporates important assumptions and simplifications, and some potentially important habitat factors are left out. Because the model was developed from limited data on basic habitat relationships, it has limited generality in both time and geography. Applying the model to the entire Oregon Coast requires an enormous expansion from these limited data, and consequently, conclusions must be viewed with caution.

The model has the unique feature of displaying how freshwater and marine survival rates interact to determine production and distribution of coho salmon across stream reaches. For example, the model predicts that extended periods of low marine survival cause extinction of coho salmon from all but the best freshwater habitats. The modelers reach the conclusion that marine survival plays the dominant role in determining sustainability of coho salmon populations. This conclusion, however, indicates a biased perspective. One could just as easily take the opposite view: that freshwater habitat is dominant because it determines sustainability during periods of low marine survival. Because marine survival can not be controlled, the best approach to ensuring sustainability may be to protect and improve freshwater habitat.

Comments below address three major areas where the model could be improved: 1) egg-to-parr survival, 2) summer habitat factors, and 3) winter habitat as a bottleneck.

1. Egg-to-parr survival

The egg-to-parr survival relationship (Figure 2) is based on inadequate data that do not represent current conditions in most coho salmon streams. The data are from a before-after study of the effects of logging in three adjacent streams in the Alsea watershed: Flynn Creek, Deer Creek, and Needle Branch Creek. Although this was a logging-effects study, the data are mostly from before logging. Flynn Creek was the control and had no logging, Deer Creek had patch cuts representing only a small percentage of the watershed, and Needle Branch Creek was clear-cut and burned, but post-logging data were excluded because the logging effects were considered too extreme (T. Nickelson, personal communication). Thus, the data are from mostly pristine areas where survival was probably higher than it is today in areas with logging and other development. Dr. K Koski, who did much of the research in the Alsea study, now believes (personal communication, 1997) that egg-to-fry survival in western Oregon streams is lower than in the Alsea study because of increased sediment and channel instability.

The model could be improved by using habitat inventory data to determine reach-specific egg-to-fry survival. Egg-to-fry survival could be made a function of sediment concentration based on sediment data from stream inventories and published relationships of egg-to-fry survival as a function of sediment concentration. Using such data would provide a more realistic estimate of egg-to-parr survival at low seeding levels.

Loss of salmon redds due to stream scour during high stream flow is included in the model, but the true extent of such mortality is probably underestimated. The percentage of redds lost to scour (15%) is based on a reasonable sample (16 redds lost out of 113 redds monitored) in an 8-year study, but all data are from mostly undisturbed streams (Flynn, Needle Branch, and Deer Creeks in the Alsea basin). Loss of redds due to stream scour is probably higher in most western Oregon streams because of watershed disturbance. Depth of scour in gravel-bedded channels reflects the rate of bed-load transport which is a function of sediment supply, discharge, and LWD loading. All of these factors can be affected by logging and other watershed uses. Even slight increases in scour depth could have significant effects on salmonid population dynamics (Montgomery et al. 1996). Therefore, the proportion of redds lost to scour should be increased and made a function of the level of watershed disturbance.

Because the loss of redds to scour probably varies greatly depending on annual peak discharge (Holtby and Healey 1986; Montgomery et al. 1996), this should be a stochastic variable in the model. Currently, the number varies only when the number of females is less than 200, in which case, the number of successful females is drawn from the binomial distribution. Perhaps a better approach would be to use the variance in the observed data from the Alsea study to define the probability distribution (but adjusted to reflect the level of watershed disturbance). These data should include the extreme event of the 1964 flood.

2. Effect of summer habitat

Although extensive studies and experience indicate that summer habitat can affect overwinter survival and smolt production, the model has no means for including such effects. For example, numerous studies have shown that overwinter survival is directly related to fish size at the end of summer, and fish size is inversely related to parr density in summer. The outlier in Figure 1 (high parr summer density but low smolt yield) may have been due to the effect of reduced fish size because of overcrowding in summer.

Some stream reaches are unfit for juvenile coho in summer because of high stream temperature. Many of these are lower reaches of streams that were not included in areas for coho production because they were not considered "available coho habitat." More explanation is needed of which stream reaches were excluded from the database because they are temperature-limited, and which temperature-sensitive streams were included in the database but do not provide rearing habitat in summer.

Effects of low summer streamflow are at least partially incorporated into the model structure because the summer habitat inventory was conducted at summer low flow. However, more analysis and explanation are needed to ensure that extreme low-flow events that may occur during extended summer droughts are adequately represented in the database. If the summer inventories were conducted during normal or wet years, they would overestimate the summer rearing area and underestimate the potential juvenile mortality that could occur in extreme drought years. An analysis should be done to determine the average streamflow conditions prevailing during data collection. If extreme drought conditions are not adequately represented, then the model should be revised to include a potential "bottleneck" in summer due to low streamflow events that recur randomly at return intervals corresponding to prevailing climatic conditions.

3. Winter habitat as bottleneck

The concept of winter habitat as the production "bottleneck" is based on extensive studies throughout the range of coho salmon showing that winter habitat is critical in determining smolt production by regulating overwinter survival of the summer parr population. It is also based on analysis of existing habitat in western Oregon, which indicates that winter habitat is in shorter supply than spawning or summer rearing habitat. However, the model incorrectly treats winter habitat as a density-dependent limit, or "smolt capacity," whereas winter mortality is usually considered to be density-independent. Further, the estimate of "smolt capacity" was based on the average density of coho in areas considered to be fully seeded. Thus, it is an average density, and not a measure of the "maximum capacity" for smolt production.

Such a maximum capacity for winter habitat is probably inappropriate in any case because, theoretically, winter habitat does not establish an upper limit or capacity, but rather provides refuge from density-independent mortality factors. For example, the proportion of coho juveniles that die in a debris torrent does not depend on how many coho were in the channel. It is not density dependent. Thus, the model's concept of winter habitat determining "maximum smolt capacity" is not supported by current habitat theory.

The assumption that winter habitat is the "bottleneck" has not been adequately tested. The relationship between smolt yield and summer parr density (Figure 1) does not justify the statement that the model has been "shown to be closely related to actual smolt production when summer habitat is fully seeded." Only five data points represent "fully seeded," and these are all from Lobster Creek. Further, one of the five points is an outlier where the highest seeding level observed produced only 50% of the predicted smolt capacity. This graph clearly does not indicate the asymptotic relationship expected if winter habitat placed a limit on smolt production. The outlier is evidence of high density-independent mortality in winter due to severe conditions or other factors.

The "bottleneck" and "smolt capacity" concepts imply that density-dependent mortality factors have compensatory effects, so that mortality is reduced at low population size. However, the winter mortality rate generally depends on fish size, quality of winter habitat, and severity of winter weather. Thus, small populations (below smolt capacity) could have quite low survival in severe winters.

The misrepresentation of winter habitat as determining "smolt capacity" leads to awkward logic, such as using winter habitat to determine the number of adults needed to fully seed summer habitat (equation 4). It makes more sense to determine full seeding based on summer habitat.

The relationship between overwinter survival and estimated smolt capacity (Figure 2) is meaningful and makes sense. Although the independent variable is called "potential smolt capacity," it is more correctly viewed as a measure of winter habitat quality (not an upper limit, but a modifier of density-independent winter mortality factors). However, the small sample size for this relationship (five streams) is inadequate for expanding regionally because the relationship could easily differ between stream types.

The most important shortcoming in the winter habitat component of the model is that the relationship for overwinter survival is based on very limited data that do not include extreme weather conditions. For example, the severe winter of 1996, which caused numerous landslides and debris torrents, is not included. Initial reports indicate that coho survived poorly even in good habitats. A storm with a return interval of about 30 years is the largest event that occurred during the study. This does not adequately reflect environmental variation, as there have been two 100-year events (1964 and 1996) in the past 32 years. Thus, the model overestimates survival because it does not reflect the low survival that can occur in years with severe weather.

References

Holtby, L. B., and M. C. Healey. 1986. Selection for adult size in female coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 43:1946-1959.

Montgomery, D. R., J. M. Buffington, N. P. Peterson, D. Schuett-Hames, and T. P. Quinn. 1996. Stream-bed scour, egg burial depths, and the influence of salmonid spawning on bed surface mobility and embryo survival. Canadian Journal of Fisheries and Aquatic Sciences 53:1061-1070.

MEMORANDUM

OREGON DEPARTMENT OF FISH AND WILDLIFE

INTRA-DEPARTMENT

DATE: 13 March, 1997

TO: Robin Waples, Tom Wainwright, Laurie Weitkamp and Steve Stone (NMFS)

FROM: Steve Jacobs

SUBJECT: Occurrence of hatchery fish in ODFW spawner escapement estimates.

Based on the phone conservation we had on 11 March I conducted the following analysis to investigate the degree of potential bias associated with ODFW's method of including only selected scale reading results to remove hatchery fish from SRS escapement estimates. This analysis indicates that applying all available scale results to SRS estimates would cause reductions in existing estimates of about 14%.

This analysis was performed as follows:

1. Scale results obtained from SRS surveys were compiled for the 5 years from 1992-96 to estimate the average proportion of wild fish in each survey stratum (Table 2). I used only these years because I had them available electronically.

2. I then computed SRS escapement estimates for each of the last 7 years (1990-96) using the actual counts obtained from the surveys (unadjusted for hatchery fish), and averaged these to obtain a 7-year average for each stratum.

3. I then applied the average proportion of wild fish from scales to the unadjusted estimate to obtain an estimate of the 7-year average escapement of wild adult spawners.

4. These values were then compared to our existing estimates to look at the magnitude of difference between existing estimates incorporating only selected scale adjustments and estimates using all possible scale adjustments.

The results of this analysis appear in Table 2. Overall, our existing estimate is 5,300 (16%) fish higher than the estimate using all scale results. Given the level of statistical confidence in our estimate of the overall escapement for this ESU of ± 25%, the revised estimate does not significantly differ from our existing estimate.

There are a number of points to consider in this analysis:

1. All scale reading is assumed to be 100% accurate, results from mark recovery in 1996 indicate that scale reading may miss-classify rearing origin.

2. Returns of hatchery fish in 1990-96 were form generally similar release numbers each year, except in 1996, when release numbers dropped sharply in some basins. Because of this, using average scale classifications from 1992-92 may somewhat overestimate the proportion of hatchery fish in the basins where releases numbers dropped.

3. As seen on Table 1, for some basins, the occurrence of hatchery fish can vary appreciably among different subbasins. In cases where subbasins are pooled as single strata (i.e. Tillamook Bay and the Nehalem), using a single adjustment proportion as I did may cause a negative bias in the estimate of wild spawner abundance.

I would appreciate any comments you may have on this analysis. It is my intent to maintain an open dialogue with you guys on these estimates to allow your decision to be based on the best available information.

copies
Nicholas
Nickelson
Bogerson

Table 2. Comparison of the mean abundance of adult coho spawners in the Oregon Coastal ESU for 1990-96 estimated from unadjusted SRS survey counts and SRS survey counts adjusted to remove hatchery fish.

		Average for 1990-1996			
Strata		Actual Counts	Percent Wild[a]	Adjusted Wild[b]	ODFW Estimate
North Coast:					
Necanicum and Elk Creek	High	548	57%	313	548
Nehalem	High	4,856	41%	20%? 1,991	2,007
Miscellaneous	Moderate	29	49%	14	29
Total		5,433		2,318	2,585
Tillamook:					
Tillamook Bay	Moderate	1,114	54%	602	903
Nestucca	Moderate	664	87%	577	664
Sand Lake and Neskowin Cr	Moderate	128	71%	91	128
Miscellaneous	Moderate	0			0
Total		1,887		1,270	1,676
Lincoln:					
Salmon	High	937	7%	66	211
Siletz	High	1,445	56%	809	977
Yaquina	High	2,342	83%	1,944	2,091
Beaver Creek	High	554	90%	499	554
Alsea	High	2,273	75%	1,705	2,064
Miscellaneous	Moderate	103	62%	64	103
Total		7,655		5,086	6,000
Siuslaw:					
Yachats	High	185	80%	148	185
Siuslaw	High	5,151	68%	3,503	4,608
Miscellaneous	High	291	83%	242	291
Total		5,627		3,892	5,083
Umpqua:					
Lower Umpqua and Smith	High	3,159	99%	3,127	3,123
Umpqua	Moderate	573	99%	567	573
Elk Creek and Calapooya Cr.	Moderate	820	100%	820	820
South Umpqua	Moderate	2,346	71%	1,666	1,934
Cow Creek	High	1,053	71%	747	879
Total		7,532		6,927	6,960
Coos-Coquille:					
Coos Bay and Big Creek	High	10,854	97%	10,528	10,593
Coquille	High	5,919	97%	5,741	5,883
Miscellaneous	Moderate	0			0
Total		16,773		16,270	16,477
Total ESU		44,907		33,444	38,780

a *Derived from classification of all scales recovered on random spawner surveys during 1992-1996.*
b *calculated as (raw count) x (percent wild).*